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The Dimension of Animal Agriculture

The staff of *Review* was particularly delighted to receive the manuscript for the lead article in this issue. One reason for this response is that we have faith in the ability of animal agriculture to maintain its position as a world protein source. We don't deny that this attitude is probably intimately related to personal preferences. Most of us would rather sit down to a plate of sirloin instead of a facsimile derived from plants. Or, to rephrase the premise in a more sophisticated fashion: People are extremely reluctant to accept what they consider to be aesthetically inferior substitutes. The plain fact is that animal products are highly desired and are readily consumed by most people throughout the world.

Our faith in animal agriculture was further bolstered by a chapter in the report of the President's Science Advisory Committee, *The World Food Problem,* released just 2 weeks before this issue went to press. One statement in this report is especially significant: "In the long run, it may be far easier to increase animal production in certain areas than to alter food preference patterns developed over many centuries."

A sizable segment of the PSAC Report deals with the contribution of wild animals to the world food supply. Apparently many people throughout the world depend on them for all or part of their animal protein. The authors of this section see a number of possibilities—including bigger harvests of wild animals and even domestication of certain species that are more heat tolerant and disease resistant than present livestock. Who knows what our search for food will lead to? Perhaps some day, when this old globe is literally crawling with people, we may even turn our attention to, say, our 4 and 20^{10} blackbirds. The thought is certainly not without precedent.—W.W.K.

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RUMINANT LIVESTOCK

Their Role in the World Protein Deficit

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WORLD leaders now recognize the potential tragedy of mass starvation if increases in food production do not keep pace with increases in population during the next 50 years. From a nutritional viewpoint, protein is expected to be the foodstuff to first become limited. In 35 countries of the three major underdeveloped regions of the world, the average per capita consumption of animal, pulse, or total protein is below minimum recommended levels according to the *World Food Budget*. The population of these countries represents 79 percent of the population of the regions and 56 percent of the world population (*2*).[1]

Studies on the contribution of U.S. agriculture in supplying world protein needs have proposed emphasis on increased production of properly supplemented cereals and high protein oilseeds for direct use as food for humans (*2*). Development of other protein sources such as algae, leaves, yeast, fungi and bacteria has been suggested (*1, 27*). Meeting these deficits with animal products has been considered impractical (*22*).

Although the emphasis on cereal and oilseed proteins has some basis, relegating animal agriculture to a passive contribution to world food deficits indicates a failure to appreciate the full impact of feed inputs into livestock production. We contend that generally accepted concepts regarding the efficiency of livestock production in terms of use of available resources are erroneous. We contend that because livestock use forages and other feeds inedible to humans, the use of limited amounts of cereals as livestock feeds can enhance the efficiency of producing proteins for humans *in terms of total food resource utilization*. Furthermore, there are promising research leads which, if exploited, can markedly increase the efficiency with which animal proteins can be produced. We also contend that considering the world food deficits solely in terms of amounts of protein or calories may result in answers which will make only the less desired diets available to the "have-nots" and may aggravate the serious sociological problems of the world rather than reduce them.

[1] Italic numbers in parentheses refer to Literature Cited, p. 7

Land and Food Resource Utilization

WHY have increases in cereal and oilseed protein production been emphasized? The partial answer can be found in the statistical problems of making world food studies. Indices of crop production can be based on reasonably reliable estimates of yield

which are assembled by acceptably uniform methods from country to country. Indices on livestock and livestock products are not practical because reliable estimates of yield do not exist in many countries. Also, there are real difficulties in taking into account the feed grain imports and the feed grain transfers from the crop to the livestock economy (*9*). The use of crop yields, particularly grains considered aggregately, also greatly simplifies the analysis (*2*). Therefore, because of the relative ease of collecting and compiling crop production data, the major studies on present and potential food production are based on grain yields and ignore livestock production.

The second reason for emphasizing grains in these studies is based on the importance of grains as a source of man's food. For example Brown (*2*) states: "Grains account for 71 percent of the world's harvested crop area; they provide 53 percent of man's supply of food energy when consumed directly and a large part of the remainder when consumed indirectly in the form of livestock products." These statements are factual and the dominant role of grains in producing human food directly or indirectly is indisputable.

However, the next basis for emphasizing cereal and oilseed crops in world food protein recommendations is open to question. The efficiency with which livestock convert protein from cereals and oilseed into meat and milk proteins is often quoted as about 10 percent and 25 percent respectively (*27*). The implication from this low efficiency of conversion is that the feeding of cereals and oilseeds to livestock to produce proteins for human food is a wasteful practice and livestock compete directly for proteins needed for humans. This implication, however, is not based on all the facts in livestock feeding. It would be true only if livestock were exclusively grain consuming animals. This assumption is not valid.

Farm animals, particularly the ruminants, have the ability to convert feeds other than cereals and oilseeds into protein for human consumption. These other feeds consist of forages, byproducts from the harvesting or processing of food crops, byproducts from the processing of animal products, and nonprotein sources of nitrogen.

Forages are food resources not generally consumed directly by humans. However, forages make up a large proportion of the rations of farm animals. About 70 percent of the protein of the average U.S. dairy cow is obtained from forages. An average beef steer gets 60 percent of its protein from forages; sheep from 80 to 90 percent. Swine and poultry, of course, use much less forage. In other countries of the world, the percentage of forage in the ration is considerably higher.

Forages, furthermore, are often grown on land which is submarginal or entirely unsuitable for producing other crops. In the United States about 191 million hectares of permanent grassland pasture and range are either privately owned or owned by public agencies other than the Federal Government (*28*). The productivity of this land is only one-fifth to one-sixth of the productivity of most cropland. However, the immense acreage makes this land an important food source when converted into animal proteins by livestock (*3*).

In addition, there are 162 million hectares of federally-owned grassland range and both federally- and otherwise-owned forests and woodland pasture and range. The productivity of this land is only 3 to 4 percent of that of average cropland. However, the importance of it as a feed source is evident from the fact that one-eighth of the livestock feed in the Mountain and Pacific States comes from Federal range alone (*3*). About 50 percent of the sheep and 20 percent of the beef cattle in the United States are in these States.

Recent trends in the United States towards greater grain consumption and less forage consumption by livestock are sometimes interpreted as irreversible results of new technology. These trends have been used as evidence to support the belief that livestock increasingly compete with humans for food. Such interpretations are not correct. The increased use of grains by livestock is a result of new technologies which have been making grains increasingly abundant and inexpensive as livestock feeds. The economic advantage of using grains is the reason for the trends. If the demand for grains as human food becomes sufficient to raise their price beyond economic levels for livestock feeds, these trends will reverse themselves rapidly. The importance of forages in livestock feeding can be expected to increase rather than decrease, particularly if the overall human food supply becomes as critical as many are predicting.

All classes of livestock use feeds which are byproducts of the manufacture of flour, starch,

glucose, and other human food items. Some of the more important byproduct feeds are wheat mill feeds, corn gluten feed and meal, distillers dried grains, and rice mill feeds. From 1950 to 1959, the annual animal consumption of these feeds ranged from 10 million to 11.8 million metric tons (*11*). Classed as low and medium protein feeds, most of them have a higher protein content than the grains from which they are derived. These feeds are not suitable for direct human consumption, but can be converted into nutritious and palatable milk and meat proteins by feeding them to livestock.

In the harvesting of crops, certain byproducts inedible to humans may be converted to sources of palatable proteins for humans by feeding them to livestock. Even though these feeds are low in protein, they provide energy needed in the production of animal proteins. One of the more important of these is dried sugar beet pulp made from extracted sugar beets. Approximately 169,000 metric tons are annually consumed by livestock in the United States. Wet beet pulp is also fed in areas adjacent to processing plants. Another byproduct from the same source—beet syrup—is also fed in large amounts.

In the meat packing industry, inedible portions of carcasses including meat scraps, intestines, and blood are processed by high temperature rendering into livestock feeds. About 2.1 million metric tons of such animal byproducts were fed to livestock in 1963.

Urea, a nonprotein nitrogen source which humans cannot utilize in their diet, can be converted to animal proteins by ruminants. It is being used extensively in dairy and beef cattle feeding and to a lesser extent in lamb rations (*12*). Approximately 127 thousand metric tons of urea are being fed to livestock annually. If soybean meal had been fed in place of urea, the requirements for soybean meal for livestock feed would have been increased by 813,000 metric tons.

The toxicity and palatability of urea is a factor in its proper utilization. However, the main restraint on increased use of urea is the availability and low price of large amounts of feed grains and oilseeds. Use of urea can be expected to increase, particularly if the demand for food proteins from cereals and oilseeds markedly increases the price of these crops.

Therefore, before concluding that livestock compete with humans for the proteins from cereals and oilseeds, one must consider the proteins that livestock produce from other sources.

Animal Input and Output of Protein

In a Wisconsin survey (*5*) of 1,500 dairy cows in 46 herds, 96 percent of the protein in their cereal and oilseed rations was returned as milk protein (table 1). Total protein input has been corrected for crop byproducts inedible to humans.

If urea had been used at recommended levels in the ration, the cows would have produced 171 kg. of milk protein from only 124 kg. of plant proteins in the form of cereal and oilseeds. Thus, protein production would have been increased nearly 40 percent by combining cereals and oilseeds with forages and urea to produce milk.

Table 2 shows the protein inputs from grains and oilseeds and the outputs from a beef cow-calf operation (*17*). An 80 percent calf crop per year and a weaning weight of 181 kg. for calves were used as bases for these estimates. Although below expectations for good management practices, these bases are probably somewhat above the actual average for the United States. These data indicate that feeding cereals and oilseeds to beef cattle does

TABLE 1.—*Protein inputs-outputs from cereals and oilseeds in a dairy cow operation* [1]

Source of input	Crude protein	
	Input	Output in milk
	Kg.	*Kg.*
1,439 kg. of grain and oilseed concentrates per year	178	171

[1] Cows producing 5,295 kg. of milk containing 3.69 percent butterfat.

TABLE 2 —*Protein inputs-outputs from cereals and oilseeds in a beef cow-calf operation* [1]

Feeding period	Crude protein	
	Inputs	Outputs
	Kg.	*Kg.*
Birth to 181 kg	0	0
181 kg. to weaning of 1st calf	27	14
To weaning of 2d calf	14	14
To weaning of 3d calf	14	14
To weaning of 4th calf	14	14
Barren	14	....
Slaughtered	....	34
Calves fed out to 454 kg	392	67
Total	475	157

[1] Based on 80 percent annual calf crop and 181 kg. weaning weight.

result in inefficient use of plant proteins. However, the management and performance levels in Table 2 were deliberately chosen below recommended practices.

Table 3 shows what is possible in beef cattle production if recommended range and pasture management practices and improved breeding are combined for greater efficiency (*8, 11, 12, 17, 19*). The beef cow produced seven calves before being slaughtered and the weaning weights were 227 kg. Such performance levels are attainable by progressive beef producers. Also, urea was substituted for grains and oilseeds in accordance with present recommendations.

Data in Table 3 indicate that with good breeding and management and the use of urea, nearly as many kilos of beef proteins can be obtained as the kilos of grain and oilseed proteins provided to the cattle. In addition some cattle are grass fattened without the usual heavy feeding of concentrates. The protein yield from these animals would greatly exceed the protein provided them from grains and oilseeds. Furthermore, no credit is given in these tables for crop byproducts such as distillers grains or corn gluten which are not used by humans but could be incorporated into rations for beef cattle.

These examples illustrate the importance of dairy and beef cattle in the efficient production of proteins for human use. This, however, is only part of the story. Promising research leads indicate that the efficiency with which cattle and sheep utilize nonprotein nitrogen combined with low quality forages can be greatly increased. Some reports have shown that nonprotein-N can serve as the sole source of nitrogen in the rations of ruminants. If such a development could be placed into practical use, it would mean that no exogenous source of protein would be required for the production of animal products by ruminants.

Nonprotein Nitrogen

IN 1949 it was shown that the essential amino acids could be synthesized in the rumen from urea (*15*). In experiments conducted in Finland (*25*), dairy cows fed a ration of urea, potato starch, cellulose and sucrose have produced in 1 year up to 4,325 kg. of milk and 164 kg. of protein without any feed source of protein. In experiments conducted at Beltsville (*20*), an Angus female weighing 132 kg. was put on a purified diet containing urea and no feed source of protein. She gained at the rate of 0.45 kg. per day to a weight of 422 kg. and produced a calf. In experiments with lambs, an average daily gain of 0.10 kg. was obtained with urea as a sole source of nitrogen, while isolated soy protein produced 0.12 kg. gain (*21*).

Although the literature clearly indicates that ruminants can produce meat and milk without any exogenous source of protein, further research is needed to increase the level of production of meat and milk from nonprotein sources. One of the difficulties is related to the timing of the release of ammonia-N in the rumen from the nonprotein nitrogen source and the release of energy from cellulose when forage is the primary energy source. The ammonia-N from urea is released rapidly after it is ingested, but the energy from forages is released slowly. In order to promote synthesis of amino acids, the release time of each must be synchronized in the rumen.

Evidence that slowing the availability of ammonia-N in the rumen will aid in its utilization is demonstrated by the fact that feeding urea six times compared to two times daily will improve gain in dairy heifers (*4*). Possible ways to slow the rate of release of ammonia-N in the rumen would be to (a) pelletize the urea, or (b) coat pelleted urea with a slowly dissolving material. Another possibility would be to develop other ammonia-N compounds or compounds related to urea which would release nitrogen more slowly in the rumen. The possible use of clathrates of urea or other ammonia-N bearing compounds may prove useful. The effect of pelleting the clathrates should also be investigated.

High Fiber Feeds

IN addition to improving the utilization of urea, the treatment of low quality forages themselves to increase their available energy would further improve the efficiency of livestock production. On the basis of projected increases in crop production in the United States, straw products alone could support an appreciable part of an increased animal population. For example, in the production of corn, wheat, etc., to feed the human population, about one-half of the dry matter is in the form of straw and is not utilized as food or as animal feed. On a total digestible nutrient basis it is estimated that by 1980 (*7*) this source of energy from grain production in the United States would be sufficient to maintain a herd of 49 million dairy cows and to produce 4,500 kg. of milk per cow per year. The present national dairy herd has about 15 million cows.

TABLE 3.—*Protein inputs-outputs from cereals and oilseeds in a beef cow-calf operation* [1]

Feeding period	Crude protein	
	Inputs	Outputs
	Kg.	*Kg.*
Birth to 227 kg.[2]	0	0
227 kg. to weaning of 1st calf	0	16
To weaning of 2d calf	0	16
To weaning of 3d calf	0	16
To weaning of 4th calf	0	16
To weaning of 5th calf	0	16
To weaning of 6th calf	0	16
To weaning of 7th calf	0	16
Slaughtered	0	34
Calves fed to 454 kg.[3]	249	98
Total	249	244

[1] Based on 7 calves per cow and 227 kg. weaning weights.
[2] Winter protein supplement as urea-molasses.
[3] Corn and cob meal with urea as supplementary nitrogen.

However, in their present form, poor quality forages such as straw have been of limited value to ruminants because of low digestibility. Furthermore, the lower the digestibility of forage because of high fiber content, the slower the rate of digestion. Likewise, the slower the rate of digestion in the rumen, the slower the rate of passage from the rumen and the lower the intake.

Therefore, methods should be developed to improve the intake and utilization of poor quality forages. Guidance in the chemical treatment of poor quality forages such as straw to make the cellulose more available can be obtained from the vast literature of the wood pulping industry. Finnish workers (*23*), using rams, have examined the effect of wood pulping treatments on the digestibility of spruce or birchwood. Digestibility of the crude carbohydrate fraction varied between 27.5 and 89.8 percent depending upon the treatment. It is estimated that the digestibility of wood before the treatment would be only about 9 or 10 percent. The technical cellulose pulp produced has a feeding value of .9 feed units or equivalent to 90 percent of that of barley.

It has been shown that the treatment of basswood by high velocity electrons alters its structure in such a way that some of the insoluble carbohydrate components become available to rumen bacteria (*14*). Extracellular enzymes in certain fungi are known to break down lignin (*16*), and might be useful in the delignification of forages to make the cellulose more readily available to the animal.

The lignin content of wood is usually 20 percent or higher (*23*), whereas the lignin content of straw is only 7 to 8 percent. This lower lignin content and the consequent need for much less drastic chemical treatment could make the delignification of straw more economically feasible than it is with wood. In experiments conducted in Norway (*13*) during World War II, straw was treated with 1.2 to 1.5 percent sodium hydroxide. The digestibility of the organic matter was increased from 42.4 to 65.7 percent. Along this line, data from Beltsville (*26*) indicate the possibility of increasing the digestibility of forages by as much as 10 digestibility units by certain ensiling procedures. The digestion coefficient (*24*) for wheat straw was increased from 22.8 to 52.2 as determined by an artificial rumen digestion technique through treatment of straw with chlorine dioxide.

In chemically treating poor quality forages to increase their digestibility, the soluble constituents probably would be recovered in the form of molasses. These constituents would be practically 100 percent digestible and would form a readily available source of energy. They could also probably be used to improve the palatability of the treated forages.

Using treated wood as a feed for animals is presently limited by economic barriers. If these barriers should change, however, wood could become a means for increasing the efficiency of livestock production. Furthermore, the possibility exists for recovering the soluble nutrients from the wood pulping industry as a molasses feed and thus preventing stream pollution. The feeding value of wood material in the form of molasses as a product of cellulose manufacture has already been examined in feeding trials with steers (*6*).

Management Needs

In addition to research on the use of nonprotein nitrogen and the digestibility of low quality forages, the potential of research on improving forage production should not be overlooked. This is particularly pertinent to developing countries where present practices in utilizing forages for protein production are extremely inadequate. In some countries, cattle are on deficit rations during the dry months and have adequate nutrition only during a few months of heavy rainfall.

We do not imply that future rations of ruminants will consist only of urea and chemically treated poor quality forages. Basic feeds are likely to continue to be cereals, cereal byproducts, and good quality forages. But as competition for food for humans increases, economics will dictate the extent to which urea and poor quality forages will be used.

Sociological Relationships

If the contribution which animal products can make to the world protein problems is arbitrarily held at a minimum and thus not fully realized, the solution to the major problem—the sociological relationship between the have's and have-not's—could be greatly aggravated. Admittedly, plant proteins lower in quality than animal proteins can be improved by combining various plant sources or by supplementing them with synthesized amino

acids. Admittedly, proteins from some of these plant sources can be provided at lower cost than animal proteins. But the fact remains that most people prefer to eat animal products, except where consumption is forbidden by law or social custom.

The FAO food report (*10*) shows that countries with the higher per capita incomes are generally the largest consumers of animal products. The availability of these products is one of the symbols of affluence to which people in underdeveloped nations aspire. Although their minimum nutritional requirements may be met by less-than-desired protein sources, their sociological needs will not be met by having to exist on second choice foods. As their incomes rise, the demand for more and more animal products will obviously also rise. Japan has already demonstrated that countries are ready and willing to pay the price for animal proteins even when they have to import such grains as are needed to supplement existing feedstuffs (*18*).

As the standard of living of people in underdeveloped countries increases, it is difficult to imagine that they are not going to demand more than the minimum quality dietary fare. Planning by the United States to meet the needs of developing countries must provide for increased production of animal products. The potential for this increase exists in the great areas of the world's grasslands and in improved management of these and other lands too rough, too dry, or too infertile for cropping. The challenge to animal agriculture is to assert its proper role in the production of world proteins by increasing the understanding of world leaders regarding the real efficiency of livestock production and to conduct the research needed in order to further improve that efficiency.

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SOIL NITROGEN VOLATILIZATION

A Case for Applied Research

LEROY H. WULLSTEIN

OF the very serious problems still confronting agricultural scientists, few appear to have instilled more confusion and engendered more skepticism than that of obtaining some reasonable consensus as to the mechanisms involved in the gaseous loss of soil nitrogen. Although Allison's treatise (*2*)[1] on the subject, over a decade ago, did much to stimulate needed research and improve communication among investigators—all of which has led to a better understanding of nitrogen losses—it appears we shall have to consolidate our studies even more if we are to approach a realistic solution to the problem. But in our efforts to clarify the mechanisms and pathways of loss, we have neglected, to no small extent, the economical necessity for reducing gaseous nitrogen losses in the field.

In part we may be rationalizing that because we incompletely understand the basic chemistry involved, we cannot therefore significantly reduce soil nitrogen deficits through applied research and management. Clearly this is not to suggest that we deemphasize fundamental approaches, but rather to say we might achieve some practical solutions if we were to incorporate into our existing programs new experiments aimed directly at reducing field losses of soil nitrogen. In this regard let us not forget the ubiquitous nature of soil nitrogen deficits in that they are reported for agricultural soils the world over (*14, 16, 20*). And furthermore the magnitude of nitrogen volatilization may be considerable.

Bollen (*5*), for example, reported a conservative estimate attesting to the loss of approximately 300,000 tons of soil nitrogen by denitrification in the United States alone during 1957. The total nitrogen deficit in the United States for the same year was estimated to be about 6 million tons.

Recent Trends

CLASSICALLY, soil microbiologists have held that the microbial reduction of mineral nitrogen (nitrate, NO_3^- or nitrite, NO_2^-) to nitrogen gas or gaseous nitrogen oxides via denitrification constituted the major pathway of gaseous nitrogen loss from soil. On the other hand, there is increasing evidence that what appear to be strictly nonenzymatic pathways may be responsible for a greater portion of the loss than previously supposed.

Perhaps the most puzzling and probably the most studied pathways of loss in the last decade or so are those involving the nitrite ion in so called, well-aerated substrates considered to be slightly or moderately acid. Volatilization under these conditions

[1] Italic numbers in parentheses refer to Literature Cited, p. 12.

is seemingly nonenzymatic due to the apparent aerobic conditions. And yet, because of the mild pH values encountered, it suggests that the mechanism involves more than direct acidic decomposition of the nitrite. Indeed, the interpretation would most likely be an enzymatic one if it were not for evidence obtained by using techniques that permit the maintenance and monitoring of atmospheric concentrations of oxygen in closed experimental systems. The nonenzymatic hypothesis, however, gains additional impetus where the evidence is confirmed in systems which have received sterilization treatments such as gamma radiation or autoclaving.

In 1960 Clark and coworkers (*10*) reported that relatively large nitrogen deficits occurred in soils they amended with urea or potassium nitrite. They concluded that these deficits were nonenzymatic and that the volatile products may have been nitric oxide or nitrogen gas. The soil systems studied were considered to be oxidative; significantly, the largest deficits occurred in those soils of only moderate or slight acidity. Prior to this report it was generally accepted that the nonenzymatic gaseous loss of nitrite required relatively strong acidic substrates—that is, below pH 5.0 or 4.5 (*3, 21*). Thus, there was reason to suspect that some unrecognized soil factor(s) or mechanism was involved in these losses.

Clark and Beard (*9*) later presented data that suggested organic matter was related to such losses, although they did not propose any chemical mechanism or pathway through which the organic matter was participating. They had the opinion, however, that amino groups were not reacting with the nitrite to produce nitrogen gas, presumably because the substrate pH was too high for such reactions to proceed.

Chao and Kroontje (*8*) stressed the importance of pH as it affects the chemical form of a given nitrogen compound, which in turn has great bearing on the energy of formation of that compound. They concluded that "In acid solutions nitrite will thermodynamically undergo three reactions: it may decompose to nitric oxide and nitrate, oxidize to nitrate, or be reduced to nitrous oxide." It will be remembered, however, that reactions appearing to be thermodynamically spontaneous do not necessarily proceed without the presence of some critical factor(s) such as catalysts which may function to reduce the energy of activation.

It is noteworthy that the sophisticated experiments of Cady and Bartholomew (*6*) indicated that acidic decomposition of nitrite does not sufficiently define the reactions involved in the formation of nitric oxide; that is, the conventional equation:

$$3NO_2^- + 3H^+ \rightleftarrows NO_3^- + H^+ + 2NO + H_2O$$

is an inadequate explanation. Also Wullstein and Gilmour (*24*) reported little or no nitric oxide production when they attempted to react potassium nitrite with hydrochloric acid at pH 4.0. Allison (*1*) also stressed that additional fundamental research is needed to clarify the reactivity of nitrite as it relates to volatilization.

Reuss and Smith (*18*) reported the formation of nitrogen gas and gaseous nitrogen oxides nonenzymatically and concluded that, "N_2 gas is formed by chemical rather than microbiological action and is the result either of a reaction of HNO_2 with soil constituents or of a reaction catalyzed by soil constituents." Thus, in the last decade investigators are beginning to realize that unrecognized factors or reactions appear to be necessarily involved in the nonenzymatic decomposition of nitrite under conditions of moderate or slight acidity. In 1963 and 1964 it was reported (*24, 25*) that transition metals in the reduced state such as Fe^{++}, Cu^{++}, Mn^{++}, etc. are factors in the nonenzymatic formation of nitric oxide from nitrite. A general equation may be written:

$$M^{++} + NO_2^- + 2H^+ \rightarrow M^{+++} + NO + H_2O$$

where M is the transition metal. Of course such oxidation/reduction equations are handy for accounting purposes, but have little interpretative value. That is to say, they tell us very little about the actual chemical mechanism in operation.

In 1965 Mortland (*17*) published data attesting to the participation of transition metals in the formation of nitrous oxide (N_2O) from nitric oxide in clay minerals. Also in 1965, Wullstein presented data during a series of seminars held in the United Kingdom which suggested that nitrogen gas may be nonenzymatically formed on reacting nitrite and transition metals in solutions of moderate acidity. It was suggested then and again in 1966 (*22, 23*) that nitrite and active metals may form transition metal complexes from which nitrogen gas and nitrogen oxides may be generated. These data, obtained

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with gas chromatographic techniques, generally agree with recent findings in which mass spectrographic methods were used.[2] Chao and Kroontje (*7*) have also obtained similar results with the mass spectrograph.

Methods of Interaction

WHILE it would be inappropriate at this time to attempt a discussion of stereochemistry and bonding in transition metal complexes, it may be of value to present a working or hypothetical model which may partially define how transition metals and inorganic nitrogen interact in soil. The oxidized state of a transition metal (M^{+3}) may be reduced through biological respiration or directly by organic matter—for example, dissimilated organic acids (fig. 1). The reduced metal (M^{+2}) may in turn be reoxidized by NO_2^-, the latter then forming gaseous NO. Of course NO_2^- and NO could enter directly into metal complex formation which may be inorganic or organic but in either case would be regarded as a reducing system. A classic example of an inorganic complex is frequently noted chemically as:

$$[Fe^+ NO(H_2O)_5]^{+2}$$

This complex is perhaps more familiar as the "brown ring" formed in the analytical technique employing iron reagent for detecting nitrite. Depending on such factors as aeration and acidity—which would be expected to affect the activity of the complex—N_2O, N_2, or NO may be formed as primary gaseous products. It may be, however, that N_2O functions as a precursor in the formation of the N_2. The NO released in the presence of O_2 would be expected to form NO_2 which normally equilibrates with its dimer N_2O_4 under aerobic conditions.

It is difficult to imagine that either strictly organic or inorganic constituents in agricultural soils are reacting exclusively of each other. It appears far more rational that both organics and inorganics would be intimately involved. Especially does this seem reasonable since organic fractions can serve as adsorption sites for metal cations and therefore may function in concentrating transition metals. These and mineral adsorption sites, or combinations thereof interacting with dissimilated organic

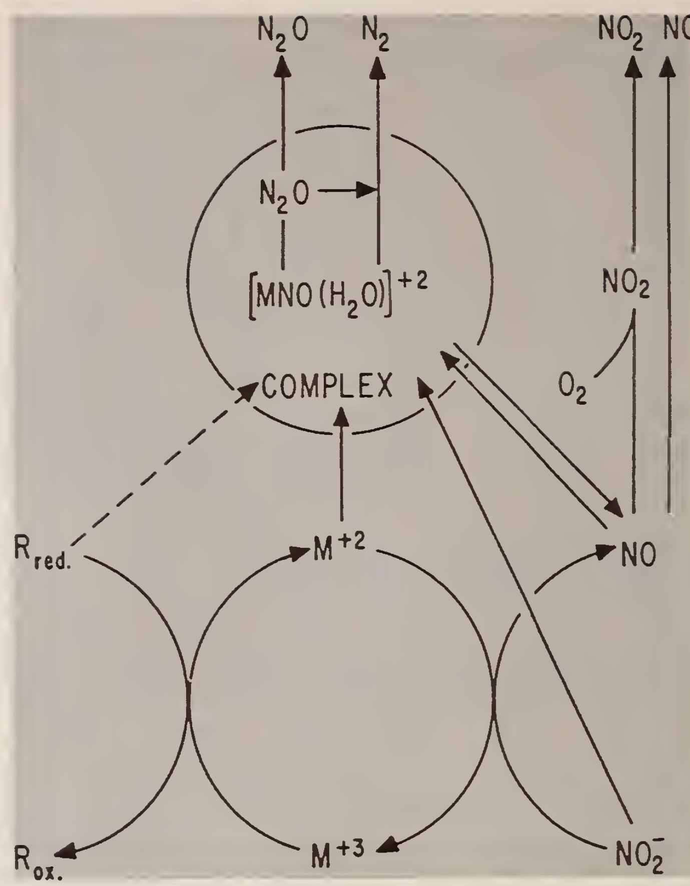

FIGURE 1. Hypothetical model of transition metal and inorganic nitrogen interactions. ^{R}red.=reduced organic matter; ^{R}ox.=oxidized organic matter; M=transition metal; →indicates organic matter may also enter into complex formation.

acids and extracellular enzymes as well, would appear to be favorable for metal complex formation. In view of the considerable capacity (*11*) of nitrogen compounds, both organic and inorganic, to enter into various complex formations, we might sometimes better refer to non-enzymatic losses in soil systems as being noncellular or extracellular volatilization.

Relevant to enzymatic reactions, Gilmour *et. al.* (*13*) have reported data which indicate a strain of *Pseudomonas stutzeri* is capable of using nitrate-oxygen and molecular oxygen simultaneously as hydrogen acceptors, with the concommitant reduction of NO_3^- to NO_2^- in well aerated cultures. These observations might be confused with the older concept of "aerobic denitrification." However, aerobic denitrification should properly be considered a misnomer by any conventional standard since denitrification *per se* implies strictly anaerobic respiration resulting in the formation of gaseous nitrogen products through the reduction of nitrate and or nitrite.

[2] Personal communication from C. M. Gilmour, Oregon State University.

Skerman and McRae (*19*), in particular, reported strong evidence negating the concept of aerobic denitrification. Most soil microbiologists have subsequently agreed that this unfortunate term resulted from inadequate aeration techniques which led some investigators to believe they were observing something new in denitrification when in all probability they were not.

Data from the recent findings of Gilmour and his associates might best be considered at this time as indicative of an additional or fourth type of nitrate use, since Klyver (*15*) recognized three basic kinds of nitrate utilization which included denitrification *per se* or "true dissimilatory nitrate reduction". An additional point relates again to the high priority to be placed on immaculate technique and control in volatilization studies. Where sterilization methods are not carefully followed or in fact are omitted, particularly in soil systems, the interpretation of the mechanisms involved becomes highly speculative.

Other investigators of nonenzymatic pathways are currently giving ammonium-nitrite reactions closer scrutiny (*1*). The kinetic data presented by Ewing and Bauer (*12*) suggest these reactions may contribute to greater magnitudes of loss than previously expected in agricultural soils. Blasco and Cornfield (*4*) have recently reported that ammonia volatilization can occur even in acidic soils and have suggested this may be due to alkaline producing minerals within the acidic substrates. Of substantial bearing on these and volatilization studies in general is the data obtained by Young *et. al.* (*26*) who reported approximately a 90 percent reduction of nitrate to ammonia in aqueous iron suspensions at pH 3.0 and almost a 20 percent reduction at pH 5.0. Thus it appears that transition metals also participate in reactions involving nitrate and ammonia.

Suggested Approaches

DEFINITIVE studies on soil nitrogen which may be expected to further clarify the mechanisms of volatilization will likely include:

a. The synergistic effects among such soil components as organic acids, transition metals and clays.
b. The chemical nature and reactivity of transition metal complexes extracted from soil.
c. Interactions between extracellular enzymes and transition metals.

Perhaps of greatest significance will be studies aimed directly at the control of nitrogen losses. Although our present understanding of fundamentals is obviously incomplete, we might at least initiate some screening tests on the basis of present knowledge which has been accumulating for more than half a century.

Where established management practices do not appear to be effective, or only partially so, several approaches remain available for expediting practical solutions to the problem.

Fertilizer technology programs, for example, could be expanded to include the testing of commercial formulations for their capacity to form nitrogenous gases. Although numerous field experiments attest to large deficits of applied nitrogen in soil, there is very little information on the extent of gaseous loss that may be directly attributed to fertilizer formulations *per se*—that is, independently of soil. In this regard it may be mentioned that G. M. Volk, Florida, is conducting tests on urea preparations.

A parallel approach to general testing would be to initiate a selective screening program to search for low-cost, potential inhibitors or reactions suspected to be responsible for the nitrogen deficits already encountered in many of our agricultural soils. It is implied, depending of course upon test results, that inhibition studies would also apply to commercial fertilizer mixtures. Whether soil or fertilizer constituents are responsible for promoting nitrogen losses—or indeed where both may be involved through interactions—seemingly, a proven inhibitor may be most efficiently applied in combination with the usual fertilizer formulations.

In view of the recent operational guidelines set forth by the Subcommittee on Production Processes for the International Biological Program, it is plausible that the reduction of nitrogen losses in soils of agriculturally depressed regions will be emphasized. That is to say, that improved production may be achieved by this approach as well as by promoting nitrogen fixation mechanisms. If this is accepted as a valid and pragmatic viewpoint, then it would follow that an early priority be given to evaluating the volatilization potential of untested soils. This knowledge would then allow corrective measures to be decisively taken when the correct solutions themselves have been adequately determined.

To further delay, and continue to persist and even acquiesce with the thesis that we must pursue the more fundamental before attempting the practical—this, in my opinion, is an erroneous argument. Complete or absolute solutions to broad problems are rarely if ever achieved. Again and again in the historical record we witness that partial solutions are the stuff upon which human advances are based. Thus, I would reiterate that we now possess substantial knowledge of numerous causative factors involved in the gaseous loss of soil nitrogen. And yet we generally lack the means, although not the ability, to conserve this nitrogen.

Sooner or later we shall come to realize that increasing the input of soil nitrogen will not in itself be an economic solution to the subsequent gaseous waste of this nitrogen. Logically, the proper solutions will include effective control of the causes. For this to become a reality, close cooperation between industry, State, and Federal laboratories will be essential. To those who might suggest that this is premature, I would add that we have already observed high achievement in applied research. And who among us would have delayed the search for the control of disease because we were unable to completely define cause and effect?

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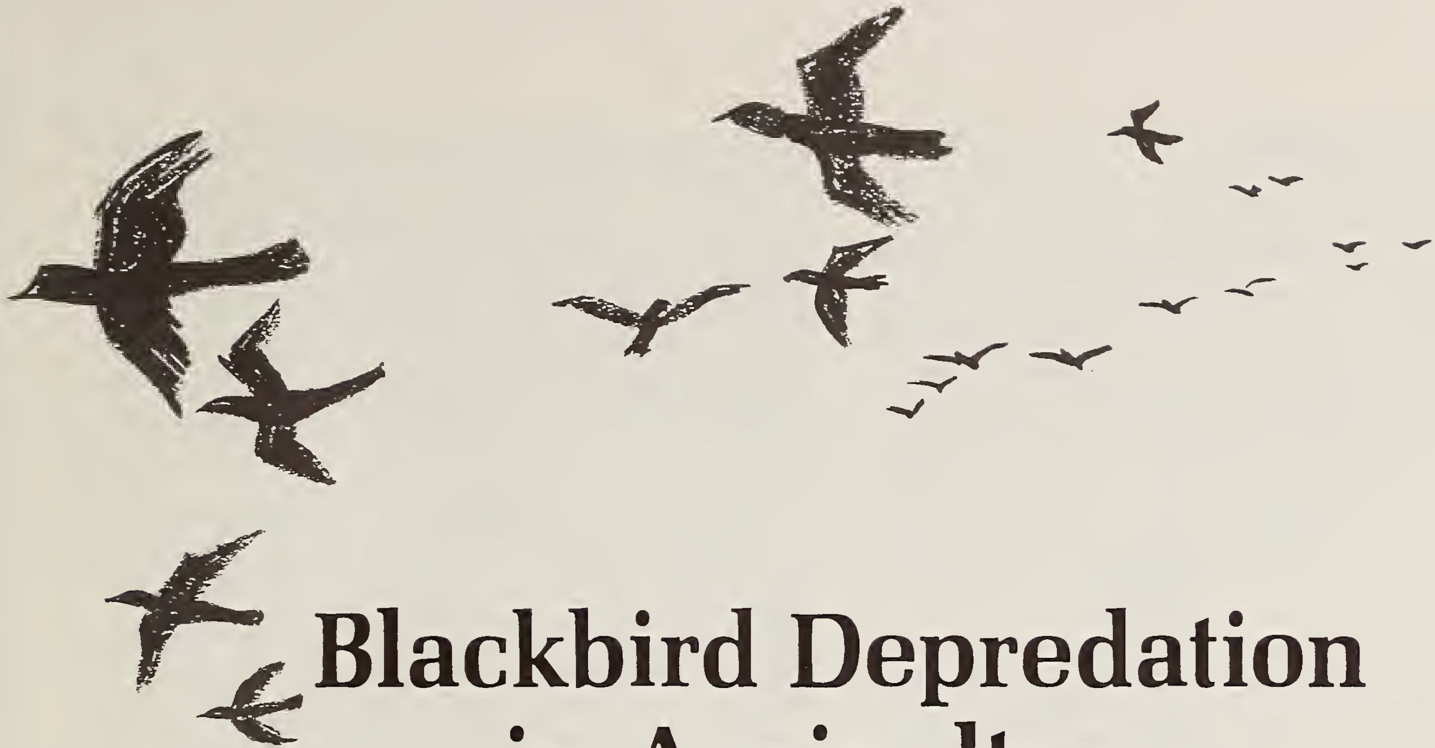

Blackbird Depredation in Agriculture

A Report on the 1967 North American Conference

EVER since man began cultivating agricultural crops for his own food use, he has had to share a portion of his harvest with various wildlife species that found it palatable and easily accessible. Except in some isolated instances, however, the damage to crops and resulting yield losses had been largely tolerated.

But by the mid-1950's, depredation by birds—particularly blackbirds—was beginning to cause much concern in wide areas of the United States and Canada. By 1963 the problem had become so acute that a formal interregional research project was set up and approved by Cooperative State Research Service. In 1965, 15 Farm Bureau State conventions passed resolutions urging more assistance with bird problems. A similar resolution was passed at the national meeting of the American Farm Bureau Federation on December 16, 1965.

In Ohio—one of the most severely affected States—direct bird damage to corn, together with associated losses such as molding, was estimated at $15 million in 1966. Feedlot losses in Georgia were running as high as $1,000 a day. Michigan fruit growers reported that starlings and blackbirds annually destroyed more than $2 million worth of blueberries and cherries. And so the reports go. Total economic loss caused by birds is now estimated at between $50 and $100 million annually in the United States alone. Many authorities glumly predict that the bird depredation problem will become even more acute.

This, then, was the economic climate that led to the First North American Conference on Blackbird Depredation in Agriculture, held at Columbus, Ohio on March 30 and 31, 1967.

Drawing participants from all over the United States and the affected provinces of Canada, the conference represented a joint effort to pool ideas, compare results, and synthesize action. Ohio agencies served as sponsors and hosts for the event.[1]

In summarizing this conference, *Review* departs from the customary reporting format, choosing instead to adapt the proceedings to the same kind of format used in reviewing the status of a research area. Such a format, we believe, will enable readers to grasp a more unified concept not only of the conference itself, but also of the bird depredation problem as a whole. Insofar as possible, credit is given to specific statements by conference speakers through the use of italic numbers keyed to the list of participants appearing at the end of this article.

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[1] The following coordinating committee deserves much credit for setting up the program: Dean W. Simeral, Ohio Farm Bureau Federation, chairman; Richard N. Smith, Bureau of Sport Fisheries and Wildlife; Austin Ezzell, Cooperative Extension Service, Ohio; Roy W. Rings, Ohio Agricultural Research & Development Center; and Willis H. Liggitt, Ohio Department of Agriculture.

History of Bird Damage

FRAGMENTARY historical notes attest to the fact that bird depredation is not unique to our times (Gottschalk *10*). Captain John Smith wrote about the abundance of red-winged blackbirds at Jamestown in 1607, and the early Delaware colonists were so awed by the hordes of blackbirds that they named a town "Blackbird." Alexander Wilson, father of American ornithology, wrote in 1808: "The birds are seen like vast clouds, wheeling and diving over meadows and cornfields, darkening the air with their numbers. Then commences the work of destruction on the corn. . . ."

Some historical evidence also suggests that blackbird depredations on corn have existed for a long time in the upper Mississippi Valley. Hopewell Indians raised corn in Ohio in A.D. 400, as did the Coles, Eries, and Delawares in later times. Southern Wisconsin Indians picked and cured their corn while it was still in the milk stage because of blackbird numbers. Meriwether Lewis, the American explorer, reported that blackbirds were numerous in the Missouri Valley and that Indian children were given the task of shooting them with bows and arrows. And during colonial days in some towns on Cape Cod, a young man was forbidden by law to marry until he had given the town clerk a certain quota of blackbird heads (*10*).

As agriculture developed, conditions became favorable for the expansion of some bird species. Except in extreme cases, bird damage to crops was accepted somewhat philosophically. At planting time, some farmers made allowances for the expected loss by dropping an extra seed kernel in the hill. "One for the birds" was a common justification for the practice (*13*). Scarecrows and similar scaring devices were common sights in the family sweet corn patch.

Only in relatively recent times, however, has bird depredation increased to the point where it is considered a serious agricultural problem. Although periodic census-taking shows dramatic increases in populations of certain species, some observers disagree as to whether increased depredation is due to overall population increases or to greater concentrations of birds in certain areas.

The Problem Species

ALTHOUGH the conference centered attention on the red-winged blackbird (*Agelaius phoeniceus*), other species are also causing depredations in North America: starling (*Sturnus vulgaris*), common grackle (*Quiscalus quiscula*), and brown-headed cowbird (*Molothrus ater*). These four species comprise about four-fifths of the depredating populations. Miller (*17*) characterized the problem species as (a) disturbers of the peace, (b) carriers of disease, and (c) unruly competitors for food.

The starling, a European bird, was first successfully introduced into the United States by a well-intentioned bird-lover at Central Park, New York City. On March 6, 1890, 80 birds were introduced, and again on April 25, 1891, an additional 40 were released. From these early importations, the birds are now distributed over the entire continent. During the late 1940's only small flocks of starlings were observed on the west coast of the United States. Total population is now numbered in the millions.

The blackbird, a native of America, has also found conditions favorable for population increases. Data quoted by Gottschalk (*10*) for an area in Illinois indicated a 100 percent increase in redwings from 1907 to 1957. On the basis of studies by Federal and State biologists, he estimated the present total blackbird and starling population in the continental United States at about one-half billion, of which redwings comprise about one-third.

Blackbird Habits

WITH some modifications and limitations, the habits of blackbirds studied in Ohio by Giltz (*9*) are similar to those of birds found in other states.[2] Birds begin arriving from southern states in late February. The male redwings, after locating suitable nesting areas, try to entice as many females as possible into their territory. Surveys made in alfalfa fields showed an average of 3.26 females per male; in other areas, 1.8 per male.

Nesting begins in late April. Some blackbirds nest in cattail marshes, but in Ohio many more nest in alfalfa and other hay fields. Often the nest can be located by picking out the "odd" plant in the field such as mustard or dock. These weeds grow

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[2] This section is supplemented by information published in "The Red-Winged Blackbird Story" by M. L. Giltz and T. M. Stockdale, Ohio Agricultural Research & Development Center and the Agricultural Extension Service, Ohio State University, March, 1960. Copies of this circular were distributed to conference participants.

faster than alfalfa in the spring and are used to support the nest. Water appears to be a requisite when the nest is built.

The nest is a neatly woven but rather bulky basket of stems and leaves swung from the upright stems of plants. Nests are more abundant in weedy meadows than clean ones; and in lowlands than in hilly fields. Surveys show that weedy clover and alfalfa fields may harbor an average of three nests per acre, each nest averaging three eggs.

The female lays from three to five light blue eggs, scrawled, blotched or clouded with dark purple or black on the larger end. After the young are fledged between late May and early August, all ages lead a vagabond existence by day. At night they congregate by the millions to roost in marshes. From these roosts the birds swarm each morning at daybreak to feeding spots within 20 miles of the home roost. At dusk they return to the marshes.

In October and November flocks break up into smaller groups of 50 to 500 and begin moving slowly but steadily southward. New data in 1967 indicate vast flocks of birds cross Lake Erie from Ohio before they go south for the winter. Upon reaching their winter area—which ranges from northern Virginia to the Gulf states—birds continue their mass roosting habits. As many as 25 million birds may spend the winter months in the Great Dismal Swamp in Virginia. Approximately 2 million have been estimated in one roost near Montgomery, Ala.

In recent years, large old buildings in southern cities have become favorite roosting places for starlings. Thus, the problem species becomes the concern of urban residents too.

A food habit study conducted in 1959 [3] showed that, for the entire year, about 69 percent of the diet consisted of vegetable food and 31 percent animal food—mostly insects. During the nesting and fledging period, animal food made up most of the diet. But during the flocking and roost build-up period, corn was the predominant food.

Ironically, the redwing is beneficial to farmers during all periods that it occurs on the northern breeding range, with the exception of a few weeks when certain agricultural crops become its favorite food.

[3] "Food Habits and Related Activities of the Red-Winged Blackbirds in North Central Ohio." M.S. thesis by Thomas M. Stockdale, Ohio State University, Columbus, 1959.

In the study conducted by Giltz and Stockdale,[4] a high percentage of birds checked were infested with helminths—types of worms that use insects as intermediate hosts. Although parasites usually do not kill the birds, they do lower their health status. The authors point out that the seeming increase in blackbird welfare could be due in part to the fact that parasite populations are reduced through the use of insecticides on crops. Nevertheless, redwings suffer a high mortality rate during their first year. Only about 20 percent of the potential number ever reach the adult stage.

Extent of Damage

DEPREDATION of agricultural crops by problem species has now become a worldwide problem, according to Kottman (*14*). He quoted from sources which have estimated that birds destroy approximately 15 million tons of food each year in the world. The problem is particularly acute on the North American continent. Kottman described the situation in Ohio as intolerable. Since 1962, blackbird damage to Ohio crops appears to have increased 300 percent. In addition to the crop damage itself, other related losses compound the seriousness of the situation: Control costs, loss to the tax base, a general depressing effect on the economy of the affected area, and lowered farm income because of the shift to other less profitable crops not affected by bird damage.

A survey by Stackhouse (*21*) indicates the scope of bird damage throughout the United States (fig. 1). Blackbird damage to corn in the milk stage is particularly severe throughout the Middle Atlantic States, the Great Lakes region, and in Florida. Rice and sorghum fields in the lower Mississippi Valley are seriously affected. Starling depredation on fruit crops is becoming increasingly serious in various parts of the country, particularly in New York, Michigan, Washington, Arizona, and California. Both blackbirds and starlings gather at poultry and livestock feedlots where they not only eat large quantities of grain, but also contaminate it. It is suspected they they play a role in the spread of livestock disease.

State-by-State reports, particularly those from the hardest hit regions, are discouraging to producers

[4] Op. cit.

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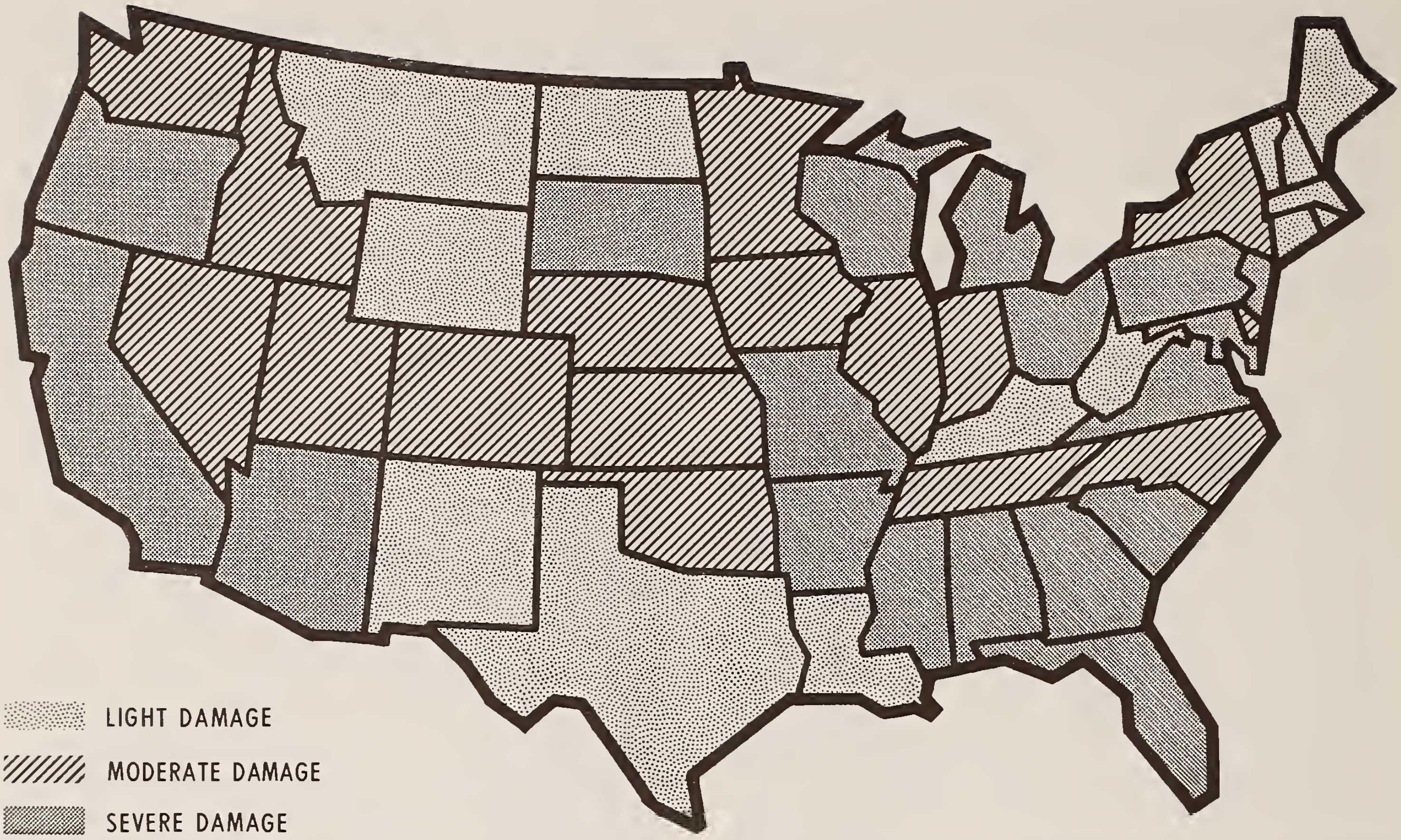

Figure 1.—Extent of bird depredation in the United States in 1966. Alaska and Hawaii (not shown) reported light to moderate damage, but not from blackbirds.

and control officials. In Wisconsin, losses from bird depredation now exceed those from corn borers. Officials in Georgia estimate a 10-million pound loss of the pecan crop each year. Ten years ago in Ohio only 10 counties reported damage. Last year 58 counties reported damage and the total direct and associated losses were in excess of $15 million.

An appraisal of bird depredation from a producer's viewpoint (Warner *22*) gave conference participants an accurate and graphic insight as to the overall problems and implications that affected farmers have to face. Warner kept detailed records in 1965 not only on the extent of damage to his 200-acre corn crop but also on control costs in trying to reduce damage.

Actual crop losses	$4, 118
Rifle cartridges	624
Carbide exploders	280
Crops sacrificed for driveways in and around cornfields	1, 900
Truck and tractor mileage (figured on an hourly basis)	600
Labor (scaring and chasing birds)	670
Total Cost	$8, 192

In this case study, fixed production expenses unrelated to control measures amount to $72 per acre. Continued losses from bird depredation, he indicated, may seriously curtail his plans to provide a college education for his seven children.

"To me, a field of lush, thriving corn is a beautiful sight," Warner commented. "But to see it riddled in a matter of hours by these blackbirds—that is a sad and depressing sight."

On a national basis, crop depredation by problem species of wildlife has now reached the point where it is seriously threatening man's food supply (Bull *2*). The same opinion was voiced by Campbell (*3*), who stated that a given area of land will support only so much life. "Which will it be—human life or wildlife?" A number of conference participants expressed the opinion that more accurate and complete appraisals of crop damage would be helpful in coping with the problem.

In addition to the crop depredation, Miller (*17*) pointed out that birds are becoming an increasing hazard to aircraft. In 1965, 1,233 bird-aircraft strikes were reported by pilots. Of these, 394 in-

volved commercial planes; the others occurred to Air Force planes. Of the latter, 294 were damaged and it was necessary to replace the engines in 75 jets.

Control Methods

As with many predators, satisfactory control of depredating birds is no simple matter. Although research is beginning to produce more effective and sophisticated control methods than have existed in the past, scaring or chasing birds from the site of the damage is still widely practiced. Actually, many affected farmers are relying almost solely on scare-device tactics. These include amplified distress calls, firecrackers, rifles, shotguns, carbide exploders, a low-flying airplane, or even a cruising car without a muffler.

The average per-acre cost for scare devices for large fields is about $5, although where bird populations are unusually heavy and the crop damage is likely to be severe, the material and labor cost of scare devices can easily run as high as $20 per acre. Moreover, although this control method, in effect, merely moves the depredation problem to another field, it does make it possible to economically raise corn. It is not easy, since the devices and patrol must be maintained from dawn to dark for at least six weeks (Giltz *9*).

Maddy (*16*) reported that blackbirds learn to ignore noise after continued exposure to it. For example, if the noise occurs at regular intervals by being activated with a timing device, the birds will soon learn the sequence and return to the fields to feed during the quiet periods.

Other control methods available to farmers (where corn is the main crop attached) include: mowing meadows a week or two early, keeping meadows free of weeds, eliminating trees or shrubs in or near cornfields, adopting a uniform planting date for corn in a given area, planting a buffer crop such as kaffir corn between marshes and corn fields, and planting bird-resistant crops. Although adoption of such methods can result in a significant difference in damage levels, they do not provide the degree of control that seems desirable. On first thought, the best plan would seem to be to switch to invulnerable crops. But such crops, for the most part, mean lower income to farmers. Some of the bird-resistant grain sorghums (thought to be unpalatable to birds because of a high tannin content) yield very well and may be used effectively in feed for cattle and poultry. Recent research indicates that certain supplements to the feed formula may make bird-resistant grain sorghums satisfactory for swine feed (Cralley *5*).

Control methods being researched by State and Federal agencies—which presumably offer more promise—are discussed in a later section of this summary.

Hindrances To Control

PRODUCERS and researchers alike are faced with a number of factors that hinder their efforts to reduce bird depredations.

In the first place, the problem species are migratory types and thus must be regarded as wildlife resources which enjoy a certain amount of protection through international treaty. For example, the Bureau of Sport Fisheries and Wildlife (Department of Interior) has an overall responsibility to all components of society for the proper management of wildlife resources (Gottschalk *10*). Most public agencies feel constrained to follow a policy of moderation in controlling problem species, although present trends indicate a recognition of the need for greater flexibility of action.

Some farmers have been critical of officials for their refusal to adopt or sanction mass extermination methods on birds while they are roosting. Stackhouse (*21*) pointed out that in Ohio, as in most other states, blackbirds may be killed only when they are damaging or about to damage a crop—except Sunday when they are protected.

Another hindrance to control is the unfavorable attitude of the public toward bird killing. Miller (*17*) cited a number of instances when legislators were deluged with protests from bird lovers as soon as they learned that control legislation was being considered. As a matter of fact the Ohio conference itself prompted a number of people to send protest letters and telegrams to conference officials (Stackhouse *21*).

Clement (*4*) stated that the National Audubon Society recognized the need for controlling some bird populations under some conditions, and was always willing to adapt its policy to the facts. He insisted that local economic interests must not jeopardize broad social values, however, and said that at present, mass reduction programs are neither practical nor socially acceptable. He expressed the opinion that current bird depredation problems are

largely a result of intensified agricultural methods, and that agricultural research had failed to take nature into consideration in encouraging intensified agricultural production. Where bird damage is localized, as in Ohio, he said the farmer must accept this as a cost of production and that if crop protection is too expensive he should be encouraged to change his crop to less vulnerable species, since the national interest was not affected by such local losses due to trying to grow the wrong crop in the wrong place at the wrong time. He added that the National Audubon Society is trying to discourage the indiscriminate feeding of wild birds, some of which has led to the creation of local problems.

Farmers in northern Ohio, aware of the need to modify public opinion about the bird problem, have formed an organization known as "Bye, Bye Blackbirds." In addition to its educational efforts, the group works cooperatively on ways and means of reducing crop damage. (Warner *22*).

A third hindrance to control relates, in a way, to a matter of simple arithmetic: problem birds in North America now far outnumber man. Because of their sheer numbers and their mass attacks on crops, State and Federal officials are finding it more difficult to handle the numerous requests for technical assistance (*10*).

Finally, although future research findings may improve the situation, our present knowledge about the world of the problem species is annoyingly scant. On this point, many conference speakers agreed. Moreover, the point was illustrated a number of times during the conference as speakers from different states found that their observations about the birds conflicted.

Status of Research

RESEARCH on bird depredation and associated problems covers a wide variety of endeavors. In general, these studies may be broadly classified in two areas: (a) crop protection and (b) bird behavior, biology, and physiology.

Considerable research has been done on the development of varieties of bird-resistant corn. These are hybrids with long, thick husks that serve as a barrier to bird damage. Although several varieties show promise, it appears that at present farmers would be just as far ahead to plant proven, higher-yielding hybrids even though they are more susceptible to bird damage (*9*). Meanwhile, the program for developing improved resistant varieties will continue.

In the area of bird management chemicals, the Bureau of Sport Fisheries and Wildlife is conducting laboratory and field studies on repellents, stupefying drugs, and avicides (Gottschalk *10*). Among the avicides, DRC–1339 is a relatively safe chemical that shows much promise for controlling starlings. It is expected to be cleared for use by the end of 1967. Avitrol 200, another promising chemical, causes affected birds to emit distress cries and fly in towering circles, thus frightening away other birds in the flock (De Grazio *6*). Experimental work has also been done on the treatment of roosting areas by spraying wetting agents from aircraft. For some unknown reason, treated birds may die at temperatures well above freezing.

Despite the advances being made in research on bird management chemicals, some conference officials expressed doubt that such control would be the answer to the depredation problem. Hewitt (*11*) cited experiments on chemical control of the quelea bird in South Africa, where as many as 40 million birds were destroyed annually. Populations the following year did not seem to be materially diminished.

Research is also being conducted on the further refinement of scaring devices. Progress in this area is directly related to increased knowledge about the habits of birds.

Trapping of birds has also been studied—not only as a means of reducing populations, but also as an aid to learning more about habits and behavior of pest birds. The number of birds captured, however, usually represents only a small fraction of the total population in an area.

Although significant progress is being made on studies of bird behavior, biology, and physiology, few of the findings have any practical application as yet. Then, too, many weak links still exist. Dyer (*7*) said research efforts have been handicapped because they have been largely limited to the use of laboratory birds. Some preliminary work, however, is being done at the University of Guelph on equipping birds with sub-miniature radio transmitters to study their habits and physiology under free flight conditions in the field. Dyer also reported some progress in studies on metabolism and heart action of blackbirds.

Two excellent color motion pictures furnished a

very useful graphic supplement to the oral presentations of the conference. One produced by the Ohio State University in cooperation with the Ohio Agricultural Research and Development Center dealt mainly with control of red-winged blackbirds in corn; the other by the Bureau of Sport Fisheries and Wildlife showed the results of new research being conducted at Sand Lake National Wildlife Refuge, S. Dak.

To impartial observers at the conference, it seemed apparent that those charged with devising ways to reduce bird depredations have a long way to go before significant gains can be recognized. Faulkner (*8*) stated that the control of bird depredation is still in the wheel-of-stone era. Krauss (*15*) pointed out that despite the heavy concentration of research effort in Ohio, bird populations and crop damage seem to be growing at an alarming rate. He cited the need for a more coordinated effort among all groups and agencies concerned. Similar pleas by other officials (*5, 13, 14, 19*) included the proposal for an international project on bird control. Presently, the only joint effort is centered in a regional project sponsored cooperatively by the U.S. Dept. of Agriculture, and nine states and the province of Ontario, Canada. Cooperating in the program is the Bureau of Sport Fisheries and Wildlife (U.S. Dept. of Interior). Individual agency effort is concentrated in the Bureau of Sport Fisheries and Wildlife, and a number of State agricultural experiment stations are conducting separate projects.

Because the problem species are still regarded as wildlife resources, primary control responsibility rests with the Bureau of Sport Fisheries and Wildlife. Several officials from this agency (Gottschalk *10*, Faulkner *8*, and Seubert *18*) cited the stepped-up research effort being given to the problem—not

only in scope of study but also in the assignment of financial and manpower resources. However, they admitted the magnitude of the problem.

Jackson (*12*) epitomized the thinking of the agricultural-minded participants when he stated that "these birds are in conflict with the interests of man."

But because of the sociological aspects involved in their control, it appears that a satisfactory solution to the problem must await the results of more research and perhaps modified attitudes on the part of the bird-loving public. In the meantime, farmers will necessarily have to continue to rely largely on "slap-on-the-wrist" techniques against depredating birds.

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ECONOMIC RESEARCH AND WORLD SUGAR PROBLEMS

ROY A. BALLINGER

THROUGHOUT its commercial history, which began after the discovery of America, sugar has been an important product in international trade and therefore greatly under the influence of the foreign trade policies of the larger nations (*4, 9*)[1]. Trade in sugar was even a contributory cause of the American Revolution, since there were objections to England's attempt to regulate the trade of New England pork for Cuban molasses.

One circumstance of importance in appraising the economic problems of sugar is the rapid increase in its world per capita production and consumption, as compared with food generally for which increases have been negligible. The International Sugar Council (*13*) reports that the per capita consumption of sugar, in terms of raw value, increased from 14.1 kg. in 1954 to 17.4 in 1962—an increase of 23.4 percent. During the same period the index of food production (consumption figures are not available) in developed countries increased only 10.4 percent and that for undeveloped countries 3.0 percent. The index of food production is weighted on a value basis and much of the increase in developed countries represents an improvement in the quality of food produced rather than an increase in physical quantity.

The rise in world per capita consumption of sugar started at least as early as 1900—the earliest

[1] Italic numbers in parentheses refer to Literature Cited, p. 28.

date for which data are available. However, the rate of increase since 1934–38 has been markedly different for different parts of the world. Per capita consumption in Africa in 1962 was 111.8 percent of the 1934–38 average; in Central America (including Mexico) the rise was 104.8 percent. Substantial but somewhat less spectacular increases of 92.1, 82.5 and 81.2 percent occurred in South America, Europe, and Asia respectively. The increase in North America was only 2.1 percent and in Oceania there was a decrease of 0.9 percent.

Actual per capita consumption is highest in North America and Oceania and much the lowest in Asia and Africa. In Europe, Central America, and South America it ranges from 34 to 34.5 kg.—about 72 percent of that for North America.

The increasing importance of sugar as a food, especially in lower income countries, is a hopeful sign amidst present world food problems. But at the same time the economic problems concerned with sugar production, distribution, and utilization are becoming more complex.

Economic Characteristics of Sugar

PRACTICALLY all the world's commercial supply of sugar—known chemically as sucrose—is produced from sugarcane and sugar beets. Sugarcane is a tropical plant from which sugar has been produced for thousands of years in India and nearby countries, but which did not become an important source of sugar to the Western World until sometime in the 15th century. Sugar beet is a temperate zone plant that has become an important source of sugar only within the last 150 years.

Because of the different climatic requirements for plant growth, only a few nations, of which the United States is the most important, support both beet and cane sugar industries. Also, it is generally true that it costs more to produce sugar from beets than from cane. Evidence for this statement is primarily indirect. Nearly all the beet sugar in the world is produced in countries that maintain some system of protection for their growers from the competition of imported sugar. In the United States, the protective system benefits both sugarcane and sugar beet growers (*10*). As would be expected from the cost advantage, nearly all of the sugar entering international trade in the world is cane sugar. Also the movement of the sugar is generally from low income to higher income countries.

One general result of the operation of the protective systems of sugar beet-growing countries is that world beet sugar production is larger and cane sugar output smaller than would be expected if international trade barriers were not present. For example, the continental blockade during the Napoleonic Wars greatly stimulated beet sugar production in Europe because the blockaded countries could not import cane sugar.

Another factor that strongly affects the sugar market is its increasing use by industrial food processors and a corresponding decline in the share purchased directly for household use (2). This trend is particularly notable in highly industrialized countries such as the United States, where about two-thirds of the sugar consumed is now purchased by industrial users.

An important consequence of the use of sugar by food industries is that the cost of most of the sugar used by the final consumers is concealed in the price of the foods purchased. Moreover, in many foods sugar makes up only a small part of the total cost incurred by the food processor. This factor has contributed to the inelastic demand for sugar, particularly in industrialized countries. As a result, when the price of sugar rises, the quantity consumed declines only slightly.

A fairly recent development which is likely to increase the elasticity of demand for sugar in the United States and certain other countries (*16*), is the increasing consumption of nonsugar sweeteners which are in part used as substitutes for sugar: (a) sweeteners derived from starch, and (b) certain nonnutritive substances that have a sweet taste. In the United States starch sweeteners are derived mostly from cornstarch and are commonly referred to as corn sirup and dextrose. In certain other countries they are called glucose. Nonnutritive sweeteners—mostly saccharin and cyclamate or a mixture of these—are manufactured from non-agricultural materials.

Although data for most of the world are lacking, starch sweeteners appear to be important in only a few countries, and even there they have attained their current usage status in the past three or four decades. Saccharin has been in commercial production since about 1900 and cyclamate since 1950. The commercial use of mixtures of saccharin and cyclamate has had its major growth since 1960. Both the starch and the nonnutritive sweeteners

appear to be used in largest volume in the United States, Japan, and England, although precise data are lacking (*3*).

Current Economic Research

EARLY economic research on sugar problems appears to have been quite meager. Much of it consisted merely of an appraisal of the advantages of some new practice or piece of equipment.

The tariff and other protective devices adopted and frequently revised by many nations have generated a good deal of economic discussion. Common questions included: (a) the extent of the protection needed by the country's domestic sugar industry, (b) preferences to be given to imports from certain areas or colonies as compared with imports from other regions, and (c) the amount of additional protection which domestic cane sugar refiners might need from the imports of refined sugar which would compete with their product, as compared with the protection accorded the raw sugar they refine.

Doubtless many of the claims and counterclaims arising from these and other questions were the result of local and temporary conditions—as was commonly true for similar claims for many other commodities. One development in the United States concerns the attempt in the Tariff Act of 1930 to establish a so-called scientific basis for rates of duty for imported products. This was to be done by determining the difference in the cost of producing the product in the United States and in the principal foreign country from which it was imported. The Tariff Commission (*21*) was given power to conduct surveys to determine such cost differences.

Among the studies conducted by the Tariff Commission was one comparing the costs of producing sugar in the United States and Cuba. This and certain other cost studies of the Tariff Commission did yield figures which were published. But they had little effect on tariff rates, although the President was given the power to raise or lower rates by as much as 50 percent. Usually, however, either the domestic industry or the importers found some reason to object to the Tariff Commission's finding, and few rate changes were made by Presidential proclamation (*22*). These studies have been discontinued.

Certain types of cost studies, however, have been continued to the present time. A number of agricultural experiment stations (*1, 8, 15, 23*) have periodically conducted studies of production practices and costs of growing beets, mainly to be able to make better recommendations to growers. Also certain cost studies on both sugarcane and sugar beet have been used to measure the relative profitableness of growing and processing the crops. Such studies provide a measure of the fairness of the prices that processors pay growers for their sugarcane or sugar beets. They also help to determine the degree of prosperity of the sugar industry as a whole under sugar prices in effect at the time. In the United States and numerous other countries where the domestic sugar industry is under some type of regulation that controls, or at least influences domestic sugar prices, the fairness of prices to producers and consumers is a matter of public as well as private interest.

Studies of the costs and profits of various segments of Louisiana sugar industry, except cane sugar refining, have been conducted at the Louisiana Agricultural Experiment Station (*6, 7*). The U.S. Department of Agriculture has also conducted confidential cost studies covering all geographic areas of domestic sugar production as an aid to administrators of the Sugar Act.

Both industry representatives and research workers in public institutions have shown considerable interest in the possibilities of obtaining increased revenue from sugarcane and sugar beet byproducts. The interest seems to have been somewhat greater for sugarcane largely because of the potential increase in income that appears to be possible from using bagasse for some purpose other than fuel (*12, 17*). The most important of these uses to date have been in the manufacture of wallboard and paper.

Some attention has been given to attempts to measure both income and price elasticity of demand for sugar (*16*). Although published information is not very extensive (consisting largely of FAO–UN studies), it indicates that elasticity is much greater in low than in high income countries because sugar expenditures commonly constitute a larger share of total expenditures in low income countries. Measurement of elasticity of sugar prices in the United States by conventional statistical methods is impractical because the Sugar Act has been administered in such a way as to produce very stable prices in the United States. Analysis based on covariance cannot yield useful results when one of the factors in the analysis shows substantially no variation.

Recently the competition between sugar and nonsugar sweeteners has intensified in the United States and a few other countries, including Japan and the United Kingdom. Attempts have been made to analyze the effects of starch sweeteners and noncaloric sweeteners on the overall market and the extent to which they have replaced sugar in the United States (*2, 3*). Little published material is available on the situation in other countries.

Some attempts to develop projections of sugar production and trade in various parts of the world have relied heavily on nonstatistical deductions (*18*). A few State experiment stations are working on the supply or acreage response of sugar beet and sugarcane growers to hypothetical changes in the prices growers receive for beets or cane. Results are not yet available.

Usefulness of Past Research

ECONOMIC information for a product such as sugar may take a wide variety of forms, ranging from the most efficient (least costly) methods of operation for growers or processors in particular areas to an analysis of the effects of international agreements on world trade and producer income in various countries. The studies by various State experiment stations on production practices, costs, and profits of beet and cane growers in particular States have doubtless been useful to growers in such States. Any measure of the importance of such findings is complicated by the fact that the use of such data is likely to be combined with the adoption of other practices related to developments made in other fields of science.

The work of the Tariff Commission on differences in cost of production in the United States and other countries appears to have had only a negative value. Experience has indicated that the results were unsatisfactory to both the domestic industry and to public bodies concerned with protecting the national interest. Two difficulties are especially noticeable. Costs among producers in any country vary widely. This raises the question: Whose costs should be considered in calculating the difference in cost? No one has proposed a satisfactory answer. The other basic difficulty is that for a country importing sugar, the costs of the domestic industry, particularly in areas of expansion, tend to rise as the degree of protection increases. That is, increased protection encourages an increase in domestic production which tends to encourage the expansion of the industry into less favored areas. Consequently the cost per unit of output increases.

Analysis of the competitive relationships between sugar and nonsugar sweeteners is relatively new and has been largely concerned with estimating the quantities of various nonsugar sweeteners used and making projections of existing trends. Some work has been done on measuring statistically the effect of price differences of sugar and nonsugar sweeteners on the relative quantities for different purposes. The results, although limited to a few industries in the United States and to a short period of time, show considerable promise.

Studies of the elasticity of demand for sugar and other sweeteners, to date, have not added much to the knowledge of the people who produce and sell these products.

The few attempts that have been made to project trends in sugar production and consumption in various parts of the world have been largely based on simple extensions of past trends modified by various nonstatistical considerations (*11*). Such attempts have considerable potential value, but there is little evidence that they have attracted much attention from public or industry representatives who have the power to alter policies so as to influence trends in one or more countries.

Needed Economic Research

PROBABLY the most important economic question related to sugar is how much importing countries should obtain from their own domestic industries and how much they should import. Questions of preferentials to be granted imports from certain countries are merely a part of the more general question (produce or import) faced by all countries that import sugar or would import it if their domestic industry received less protection.

This problem was recognized in 1947 by Black and Corson (*5*) who analyzed some of the results to be expected from various United States sugar policies. Much more work is needed—not only to update the Black and Corson study, but also to extend its scope to other countries and to include indirect effects on other products. A considerable fund of background information available from pub-

lications of the International Sugar Council and other sources would be useful in anlyzing the numerous complex factors. Existing published descriptions of the regulatory machinery dealing with sugar in a large number of countries provide valuable background material for the needed analysis.

Closely related to studies of the relative advantages of imports versus domestic production, but also of great importance in its own right, is the need for research on the present and potential effects of nonsugar sweeteners on the sugar market. The small amount of work on this topic concerns mostly the United States. The effectiveness of nonsugar sweeteners, particularly those derived from starch, as substitutes for sugar depends to a considerable extent on comparative prices. Countries with protective systems that maintain sugar prices which are high relative to those for starch are more likely to have growing glucose sirup industries—for example, United States and Japan. Other nations, primarily in Europe, have largely prevented this development by strict government restrictions on the sale of such sirups.

The need for more information about the competitive relationships between noncaloric sweeteners and sugar is even greater than for the starch sweeteners. Also, competition between a nutritive and nonnutritive substance seems to be unique; it does not exist for other foods. The extent of substitution of noncaloric sweeteners for sugar involves questions of health, weight (which may or may not be related to health), taste, price, and probably other factors. The answers may prove to be different for different nations because of varying attitudes toward these matters.

Comparatively little is known about the elasticities of supply and demand for sugar under different circumstances in different countries. One feature of these elasticities peculiar to sugar is the so-called "world" market with its violent price fluctuations. Sugar sold in the "world" market consists of exports that do not have a favored or preferential market (*20*). For instance, except for small quantities of nonquota sugar, all sugar exported to the United States is paid for at prices prevailing in this country. Such prices are commonly higher than those prevailing in the "world" market. Somewhat similar markets exist in a number of other importing countries.

Only about 10 percent of the sugar produced in the world is sold in the "world" market. The demand for sugar from "world" stocks by importing nations has fluctuated widely since the end of World War II and has been influenced by such factors as unusually large or small production by the domestic industry in some country or contiguous group of countries, or the threat of war which induces increased stockpiling especially in importing countries. For example, "world" sugar prices, which averaged around 3.05 cents per pound at the end of May 1967, rose to 3.55 cents by June 7 during the height of the Middle East crisis and then declined to 2.55 cents on June 16. Stockpiling is liquidated about as soon as the emergency appears to be over. This shifting demand is the key factor leading to the wide fluctuations in prices of "world" sugar as compared to the internal prices in most countries.

Much useful information could be gained from research studies on (a) the unstable price of the "world" market, and (b) the extent to which unexpected changes in the world's supply of sugar (which in turn creates shifts in demand in certain areas) is reflected in operation in the free "world" market for sugar. Such work should, of course, include appraisals of the effects of the system on the costs and profits of the sugar industry in various parts of the world and the indirect effects on world trade in other commodities.

A realistic projection of future trends in sugar production and consumption in various areas of the world and of the extent and direction of international trade in sugar depends heavily on the findings that may come from research in all of the foregoing areas. Also, the ability of the world to continue expanding its sugar production at a rate greater than the increase in the world population and at prices which consumers can afford will be heavily influenced by the manner in which resources for sugar production are allocated among nations. Such ability requires knowledge of the effects of the present sugar control systems on the economics of world sugar production and trade, including the effects of the use of nonsugar sweeteners (*14, 19*).

In addition to studies related to the global aspects of the sugar economy, there is need for continuing studies of a more limited nature. Studies of costs and efficiency in numerous areas and under conditions

of constantly changing technology should continue to yield valuable results. Comparatively little is known about acreage response to price changes for sugar beets and sugarcane. Information of this sort needs to be obtained for relatively small homogeneous areas. Also periodic revisions likely will be needed as conditions change.

Economic problems in sugar as well as in other industries are not likely to remain solved for any long period of time. Rather, they require more or less continuous study to cope effectively with changing economic conditions.

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Food Irradiation

L. M. MASSEY, Jr.

SINCE shortly after the discovery of X-rays, scientists have been studying radiation in an effort to utilize the results to the benefit of mankind. Only in the past 20 years, however, as the world entered the atomic age has a concerted effort in this direction been made. In the food irradiation field there have been many surprises, both happy and not-so-happy, which have led to both optimistic and pessimistic reports as to its application. Although we have come a long way in exploring areas of profitable study and clearing up the attendant problems, it is still difficult to draw definitive conclusions about the feasibility of preserving foods by irradiation.

Enthusiasm for food irradiation has vacillated widely. Early writers predicted foods treated by radiation would approach a state of suspended animation. Unfortunately, no such miraculous phenomenon occurred. Some foods became completely useless as a result of the high radiation doses necessary to completely stabilize them. Other foods that did withstand this vigorous treatment usually succumbed to degradative micro-organisms unless they were protected by sterile packaging.

As the initial over-optimistic predictions proved untrue, it is understandable, therefore, that the second reaction was one of over-pessimism. Irradiation was decried as being completely useless for preserving food. Fortunately this reaction too has proved untrue. Out of the studies of the early days of food irradiation, a significant number resulted in some promising leads. Several laboratories are currently following these leads and are conducting systematic research and development studies.

Food scientists in dozens of major food laboratories and in a number of major Federal agencies have published hundreds of research reports ranging from the most theoretical to the purely applied. Despite this activity, however, this country has yet to see the first irradiated food on the market shelf. This review makes no attempt to explain why. Instead, we present factual highlights of the problems, the achievements, and the goals that food scientists have set for themselves.

The Irradiation Process

FOOD irradiation is the process of treating a foodstuff with ionizing energy to improve its safety,

nutritive value, acceptability, or keeping quality. One important quality of ionizing radiation is that, in sufficient intensity, it is lethal to living organisms. A large amount of radiation (millions of rads) produces a sterilizing effect. Smaller amounts of radiation, however, because they kill some of the micro-organisms, can delay spoilage. Such a process is known as pasteurization.

It should be pointed out that irradiation—unlike treatment with heat—does not greatly change many foods. Moreover, at utilizable doses it does not induce radioactivity in the food. Most naturally occurring enzymes, however, are quite resistant to radiation inactivation.

Radiations most commonly used are high speed electrons, gamma rays, and X-rays. Of these, gamma rays emanating from the decay of radionuclides such as cobalt 60 or cesium 137 appear to be most feasible at present, although the advantages of electrons and X-rays emanating from mechanical-electronic devices are also great.

The energy of ionizing radiation may be transmitted to biological systems and foodstuffs in two ways. One is the actual transmission of energy from the photon of radiation to the molecule with which it comes in direct contact. These energies are considerably greater than that required to break many organic bonds, and are often dissipated in this manner. In addition to forming molecules of smaller size, various free radicals, or hyper-reactive fragments, may be formed and these may combine in unexpected and unnatural ways.

Energy may also be transmitted indirectly through the medium of water. Radiation appears to bring about formation of hydrogen and hydroxyl radicals which are powerful oxidizing or reducing agents and many subsequent interaction products. Structurally, protoplasm is a colloidal suspension of high water content. Hence a major part of the energy transferred to biological systems probably occurs via this mechanism (*3*)[1].

Although in theory any response of the foodstuff to radiation which contributes to its utility is possible, in actual practice research has been channelled towards certain relatively specific objectives. These include the complete sterilization of organisms to permit indefinite storage, pasteurization for limited storage, disinfestation of insect parasites, modification of the biochemical or physiological properties of fresh foods, and physiochemical alterations for specific purposes in processed product improvement. Within certain limitations, success has been attained in each of these areas.

The Major Problem

THE major problem in food irradiation is illustrated in Figure 1. Generally speaking, the more biologically sophisticated the system being irradiated, the more susceptible it is. For example, although higher animals are susceptible to relatively low doses of radiation, one must increase the dose about 2 orders of magnitude to reduce non-sporulating mirco-organisms to the pasteurization level, and 4 or more orders of magnitude to reduce sporulating micro-organisms to currently acceptable levels of sterilization. Although it is necessary to inactivate the naturally occurring enzymes in food to achieve stability by preventing autolytic changes, such enzymes *in situ* are extremely resistant. Thus it is obvious that to accomplish the most basic function of food preservation-protection against micro-organisms or autolysis, one must subject the commodity to a high radiation level.

Flavor and consistency of the irradiated food is often changed, frequently to the point of loss in consumer acceptance. Wholesomeness questions are also raised. Actually, the whole program of research and development of food irradiation has centered on efforts to (a) increase the susceptibility of contaminants and (b) decrease the susceptibility of the footstuff. Whatever progress is achieved in developing a satisfactory process depends to a large extent upon the success in bridging this gap.

Meat and Meat Products

PROGRESS in the meat-products irradiation program has been slow but consistent (*5, 20, 21*). The initial objective was to develop irradiation-processed items in military rations so as to provide foods of greater acceptability, improved nutritive quality, and better storage characteristics than those currently available.

Of particular importance was the possibility that irradiated products might (a) simulate natural foods more closely than cooked or dehydrated foods, and (b) withstand storage and transport without refrigeration and without significant deterioration under extreme conditions.

[1] Italic numbers in parentheses refer to Literature Cited, p. 35

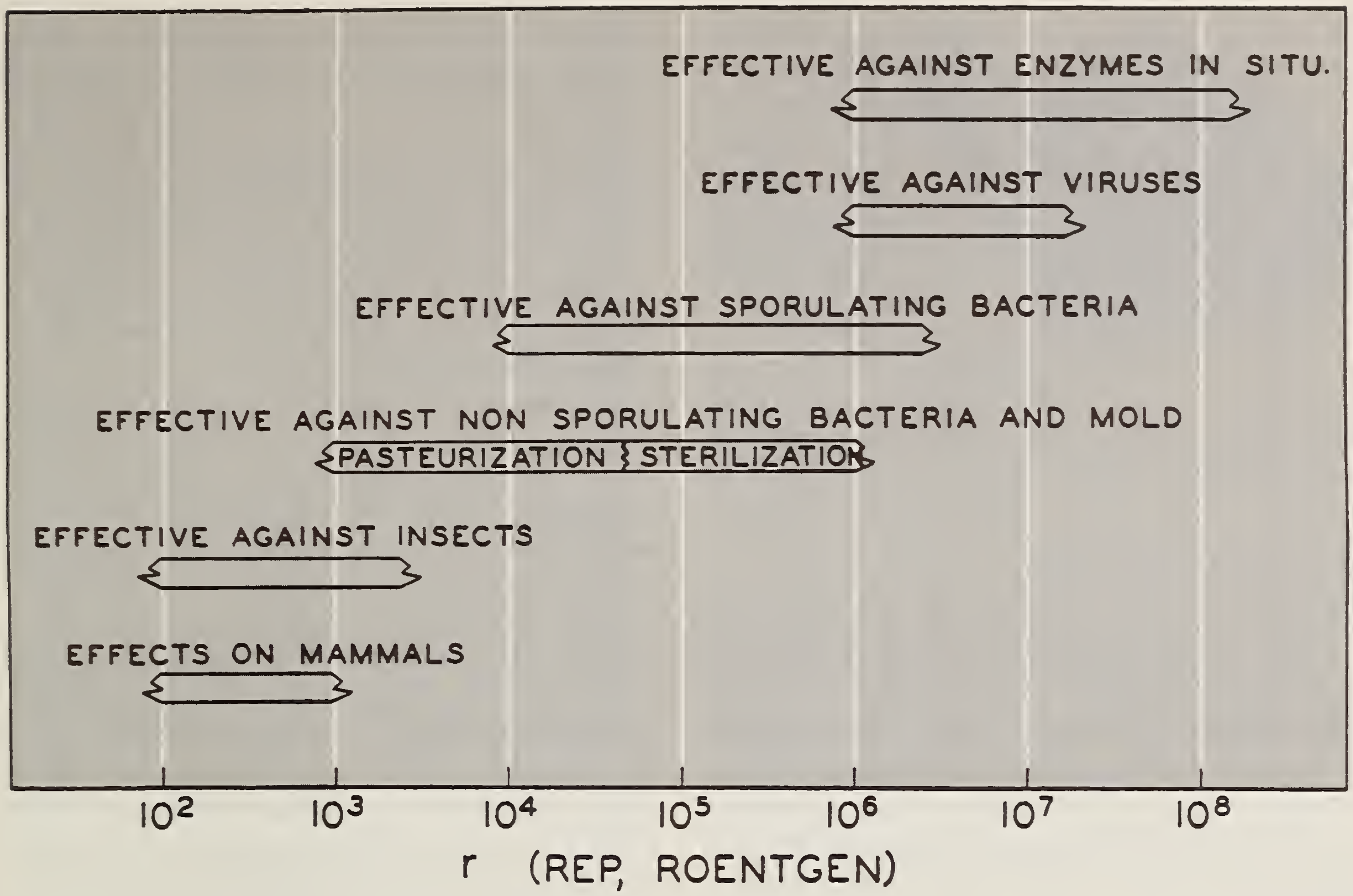

FIGURE 1.—Effectiveness of radiation on various biological systems (*10*).

To date, the only meat that has been cleared in the United States at doses capable of product sterilization is canned bacon. This product has been found to be wholesome and acceptable at doses as high as 5.6 megarad (Mrad) (*22*). Although no commercial facilities for the processing and production of irradiation-sterilized canned bacon exist at this writing, negotiations between private industry and government are essentially complete for constructing a pilot meat irradiation plant which private industry is to build with financial assistance from the Federal Government. Planned minimum capacity is 1 million pounds per year. Operation of this plant is to be stimulated by a military procurement program in canned bacon during the initial period of operation. Limited production procurement descriptions are also being prepared for other cleared items including disinfested wheat flour and sprout-inhibited potatoes.

Irradiation processing of a number of other meats is in the final development stages (*5, 12, 20, 21, 22*). These include ham, fresh pork, chicken, beef, hamburger, pork sausage, turkey, frankfurters, barbecued beef, luncheon meats, lamb, and duck. These foods have so far proven to be wholesome, safe, and of comparable nutritive value to that preserved by conventional thermal processing. Scientific and technical feasibility of irradiation treatment has been proved, and, in most cases, product flavor and texture are acceptable.

The principal deterrant to acceptability of irradiated meat is an "off" flavor best described as a "scorched" taste. This flavor is most objectionable in beef, somewhat less objectionable in lamb and veal, but considerably reduced in chicken and pork. Adding flavoring to smoked pork products such as bacon or ham tends to mask whatever irradiation flavor develops. But with beef, chemical changes during the irradiation process produce not only "off" flavor but also some loss in texture. It has been found possible to produce acceptable irradiated beef by the somewhat involved process of first heat-inactivating the autolytic enzymes fol-

lowed by irradiating to sterilizing doses at temperatures well below freezing. When properly thawed, the product has an acceptable flavor and texture, is entirely wholesome, and has a shelf-life at room temperature measured in months (*7*). Although this process is prohibitively expensive for the civilian market, it offers considerable promise as a "high morale" product for military feeding under adverse conditions.

One aspect of meat irradiation that has good potential is that of disinfestation. Eliminating worm parasites such as *trichina* from pork has been found effective at dose levels as low as 30 kilorad (*12*).

Fish and Marine Products

RADIATION processing to extend the shelf life of fish and marine products has one of the most promising potentials in food irradiation. Fresh fish are extremely difficult to keep without marked change in wholesomeness; moreover the subtle changes in color, flavor, and consistency that occur with conventional processing often mean the difference between consumer acceptance and rejection.

Heat-inactivated, 5 Mrad irradiated fish have a refrigerated shelf life of several years. Even at room temperature there is ample stability to extend fish so processed from one annual harvest to the next. However, sterilizing doses of 5 Mrad changed odor and flavor sufficiently to make the product unacceptable. A breakthrough in product acceptability at this dose level has yet be made (*9, 12*).

Although sterilization is as yet impracticable, pasteurization holds promise. Fresh pasteurized fish will retain its quality during storage at 0° C. for about 20 days and at 4° C. for about 10 days. Low-fat, white-fleshed fish such as cod, halibut, haddock, plaice, and sole are particularly adapted for such treatment; doses of 0.5 Mrad about quadruple the refrigerated storage life of these fish (*9*).

Radiation disinfestation of dried or smoked fish is being seriously considered for some parts of the world where losses from insect damage are estimated at be as high as 30 percent (*9*).

Pasteurization of marine products has raised a difficult problem. Although the vegetative cells of pathogenic bacteria such as the salmonellae or clostridia are sensitive to radiation and are virtually eliminated from foods at 0.5 Mrad of ionizing radiation, the spores of clostridia can withstand such treatments and, if they are present, can grow and produce toxin resulting in food poisoning. Most clostridia are completely inhibited at temperatures below 10° C. With fish, however, the situation is complicated by the possible presence of *Clostridium botulinum* type E. which differs from the others in that its spores can germinate and produce toxin at temperatures as low as 3° C.

In unirradiated fish, other putrefactive bacteria make the fish inedible before the toxin has had a chance to develop. But with irradiated fish, it is considered possible that growth of such bacteria could be depressed to the point where consumers could no longer rely on this natural warning system. Safeguards against such an occurrence are being explored. One of the best is storage of treated fish below 3° C. Although this might be relied upon as effective for the wholesaler or retailer, it is not an acceptable safeguard at the consumer level. Of course since fish is not commonly eaten raw in the U.S., the cooking process destroys the toxin and the chances of food poisoning are further reduced. Further processing steps such as combined heat and irradiation or the addition of some Type E growth-inhibiting substance are being investigated.

Until additional positive control of this potentially dangerous situation is provided, radiation pasteurization will not be approved as a preservation process despite its many distinct advantages such as retention of wholesomeness in the product.

Fruit and Vegetables

SUBJECTING fruit and vegetables to sterilizing doses of ionizing radiation has been found to have excessively high deleterious effects upon quality, particularly texture. It may eventually be possible to reduce the sensitivity of the tissue we wish to sterilize while at the same time increasing the sensitivity of the organism we wish to kill. Active research is currently being conducted in this area; the possibilities for eventual success are fair. At this time, however, most emphasis is being placed on treatments in which the doses are below that required for sterilization.

Relatively low radiation doses, however, have the capacity to decrease spoilage in many fruit and vegetables without undesirable effect. Examples are brown-rot control on peaches and cherries, or other

decay on strawberries and numerous other fruits. These are promising areas of investigation (*2, 6, 9, 12, 22*).

Unlike meat or dairy products, fruits and vegetables are living tissue. Therefore, it is necessary to consider the effect of ionizing radiations upon life processes. Shelf-life extension by modifying the physiological or biochemical processes of the commodity itself is, consequently, one of the important aspects of food irradiation. Investigation of the potential of this interesting aspect is only just beginning, and much work will have to be accomplished before its full potential can be evaluated.

One of the most involved aspects of radiation processing is its influence upon respiratory mechanism and activity (*13, 14*). Because of the relation between respiration and the ripening rates of fruits and vegetables, much attention is being directed to modifying ripening rates indirectly through radiation-induced changes in respiratory mechanisms. Some varieties of the banana, for example, ripen much more slowly and more uniformly and remain in the ripe-for-eating stage longer if they are treated to low doses of gamma radiation (*16*). Responses may differ depending upon the maturity of the commodity at the time of irradiation. Apples, for example, which are irradiated at early harvest respond quite differently than when irradiated in a more ripe condition (*15*). A marked difference in physiological responses is indicated by the fact that irradiation at early maturity markedly increases respiratory O_2 uptake but not CO_2 evolution, whereas irradiation of mature fruit increases both.

When one considers the large variety of edible fruits and vegetables—each with its own particular characteristic of ripening under a variety of handling and storage conditions—it would be very surprising if a number of beneficial applications did not develop. One interesting finding is that apples irradiated with pasteurizing doses of ionizing radiations are not as susceptible to storage scald and brown core as untreated fruit (*15, 17*). The precise causes of these physiological storage disorders are not known; neither are we certain as to why radiation can control them.

Research has shown that tissues become more "mealy" in texture with increasing doses of radiation. At present we know of two mechanisms that contribute to this effect. First is an actual degradation of the pectin substance which cements the tissue

cells together (*4, 13*). Thus, the tissue tends to be pulled apart rather than being fragmented by a shear force. Destruction of pectin can be demonstrated in the tissue itself as evidence by the decrease in average molecular weight of extracted pectin. Moreover, chemically pure pectin may be degradated by radiation. In our work at Geneva, we have studied the nature of this reaction, and have even been able to reverse it in model systems (*23*). How to bring about such reaction in foods is yet to be shown.

Another response to irradiation resulting in a softening of the tissue is the apparent decrease in water-holding capacity of cells (*13*). Plant cells show a substantially reduced turgor pressure and the tissue becomes wilted. Although we do not know the mechanism by which this change occurs, we do know that very substantial permeability changes are brought about by the irradiation process.

A number of color changes—other than the one in storage-scald—have been noted during the irradiation of fresh fruits and vegetables with very high doses. These include bleaching of the green color of such items as lettuce, beans, and peas, as well as reduction in intensity of various pigments such as lycopene in tomatoes and anthocyanin of cherries (*6*). Although color change is undesirable, it is usually less important than softening. In some cases, when the causes are known, it has been possible to control these color changes. For example, the yellow spotting occurring on irradiated lettuce is a secondary injury of the tissue caused by the presence of radiation synthesized ozone (*11*). This injury can be almost completely controlled by irradiating lettuce in an atmosphere devoid of oxygen and hence free from the offending ozone.

One use of irradiation is to control sprouting in such vegetables as potatoes. Particularly in countries where it is not possible to produce more than one

crop a year, low-dose control of sprouting will permit carryover. Generally, the more metabolically active the tissue, the more sensitive it is to radiation inactivation. The bulk of the potato tuber is composed of cells that are principally used for carbohydrate storage. The respiratory activity of these cells is very low, and they are quite resistant to changes by irradiation. On the other hand, the meristematic cells of the potato eye are considerably more active and more susceptible to irradiation. A dosage of, say, 7,000 rads, which may be detrimental to the development of the eye into sprouts, does not adversely influence storage cells (*19*). Unfortunately the meristematic cells of the cork cambium which are normally responsible for healing abrasions to the skin of the potato during storage are also damaged by this dose of irradiation. Therefore, care must be taken not to bruise irradiated potatoes or they may succumb to desiccation or to the invasion of rot organisms. Onions and other vegetables may also be prevented from sprouting with low doses of irradiation.

A characteristic effect of irradiation is change of flavor. Unlike meats where the process generates "off" flavors, fruits and vegetables usually suffer more from loss of flavors. Fruits that have a characteristic "bouquet" are the ones that suffer most. The use of certain free-radical or electron acceptors provides some assistance in reducing this destruction with processed foods, but it is doubtful that it will be of much value with fresh fruits and vegetables. Aside from the aforementioned instance, however, the flavor problem with most fruits and vegetables appears to be relatively minor.

Without a doubt, one of the greatest immediate potentials of irradiation processing of fruits and vegetables, as well as fruit and vegetable products, is insect disinfestation. The inroads of insect destruction and loss in potential income through quarantine restrictions to trade is beyond calculation. It has been demonstrated that rather low doses can frequently completely control many insect pests and cause little or no measurable effect upon the commodity. The importation of mangoes and papayas from Hawaii into the continental United States is severely restricted because of quarantines on oriental fruit flies, melon flies, and other tropical insects. A market potential for mangoes alone of over $13 million has been estimated. The potential savings of insect disinfestation of cereal grains on the world basis is staggering. Several pilot plant grain irradiators are currently under construction.

An interesting process for the improved rehydration of dehydrated vegetables has been developed and is presently in the final stages of wholesomeness testing. This process is unique in two ways: (a) it is the product of private industry research and development; and (b) it utilizes radiation processing as an adjunct to conventional process methods as a means of product improvement. It is claimed, for example, that such treatment of dehydrated soup mixes not only shortens cooking time but also improves product quality over conventionally processed products (*20*). Other reports state that the dehydration rates of certain fruits and vegetables may be considerably shortened by pretreatment with relatively mild doses of radiation. This area of process improvement is one which warrants serious consideration in food processing research laboratories. To date the potential of this process has scarcely been touched.

Wholesomeness

THE wholesomeness of irradiated foods has been a topic of considerable controversy. According to the U.S. Food, Drug and Cosmetic Act, irradiated foods must be considered as adulterated unless specifically exempted. Investigations have been conducted since 1954 and include extended feeding studies. Following preliminary toxicity and nutritional studies in which no evidence of toxic effect was found, long-term animal tests were conducted principally on dogs and rats. The purpose was to determine possible chronic toxicological effects, carcinogenicity and nutritional adequacy of 21 representative 4.5 and 5.6 Mrad gamma-irradiated foods through several generations or for 2 years. Studies included growth, reproduction, longevity, lactation, tumor incidence, histopathology and evidence of metabolic change. During these studies it became apparent that vitamin loss did occur when the foods were subjected to high doses of irradiation. However, the degree of vitamin destruction in irradiated foods was about the same as that in heat-processed foods, and could be readily overcome by supplementation if necessary. No other deficiency or any clinical or histopathological abnormality which could be specifically attributed to irradiation was observed. From these studies it was concluded

that "foods irradiated up to absorbed doses of 5.6 Mrad with cobalt-60 source of gamma radiation or with electrons with energies up to 10 million electron volts have been found to be wholesome; that is, safe and nutritionally adequate" (*18, 20*).

A few reports have indicated that it is possible to demonstrate toxic and mutagenic effects of certain food constituents to micro-organisms, plants, and animals when conducted under certain often quite specialized conditions. At least one of these studies attracted considerable attention both within the scientific community and in the press (*8*). It is apparent from numerous studies conducted by several laboratories that the amount of induced radioactivity in foodstuffs treated with sterilizing doses of either cobalt 60 or cesium 137 radiation, or up to 10 MEV electrons, is either completely absent or at most borderline upon being detectable with the most sensitive means of measurement presently available (*5*). Certainly any induced radioactivity is entirely insignificant in terms of the amount of naturally occurring radioactivity which has always been present in the food of man. Clearly, what is involved here is known or unknown chemical degradation products resulting from reactions within the food of primary or secondary products of high energy sources. Research on conventional feeding has failed to discern any ill effects (other than the relatively inconsequential vitamin destruction) from the long-term consumption of irradiated diets by test animals. Nevertheless, it is important to explore any evidence based on sound experimental research that indicates any possible hazard by the inclusion of irradiated foods in the diet. Such research should be encouraged, and the results confirmed by other laboratories, and interpreted in the light of all the data.

Acceptability

A VITAL aspect of the food irradiation program is whether the products of irradiation will be accepted by consumers. As has been demonstrated, it is possible to advantageously treat a number of foodstuffs with radiation without noticeably lowering the quality. How the buying public will react to foods so processed and labeled is very largely an unknown factor at this time. One study conducted in Canada on market distribution of irradiated potatoes showed no discrimination in acceptability. It seems likely that the U.S. public will accept irradiated foods and will consume them indiscriminately with unirradiated foods if they find it advantageous to do so. There should be some positive benefit to the process, such as the availability of an otherwise unavailable item, notable increase in quality or safety of the product, or lower cost. There is reason to question, however, whether the buying public—even as well educated and quality conscious as that of the United States—will readily accept a product of no particular advantage which is associated with the word "radiation".

A number of recent articles have decried the relatively slow advance made in the commercialization of food irradiation. Despite a number of economically attractive food irradiation applications available to industry today, both government approval and industry interest have lagged. It should be recognized that now is the time to iron out these disturbing details of quality and wholesomeness. One incident involving acceptability or public health could set the program back more *after* commercialization than a number of such questions raised *now* and settled in the ordered sanity of the research laboratory.

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IBP

A QUARTERLY REVIEW OF THE INTERNATIONAL BIOLOGICAL PROGRAM

Phytopathology and the IBP

In March 1966, an *ad hoc* group of plant pathologists [1] developed outlines for three research areas that would be of interest to the American Phytopathological Society.

1. *Origin and sources of pathogens of some major crops*—The continued appearance of new pathogens and strains of old ones that are virulent to supposedly resistant varieties of plants has reduced many programs of breeding for disease resistance to a stop-gap basis. Research under this proposal would be directed toward: (a) determining the origin and sources of plant pathogens, (b) bringing together plant pathogens from many sources for comparative studies, and (c) studying the variation in plant pathogens including the full range of variability of which each of the important species is capable with regard to pathogenicity, physiology, and morphology.

2. *Spore load in the atmosphere, its measurement, distribution, and assessment*—The objectives of this study are to determine: (a) what plant pathogens are present, (b) where they may be originating, and (c) their significance to world food and crop production. Research would be conducted on a worldwide basis to learn about the spore loads—kinds, viability, pathogenicity, and distribution patterns. The report of the first meeting of SCIBP stated: "It is recommended that SCIBP stress the need for and encourage investigations of the atmosphere as a medium of international dissemination of plant and animal pathogens . . . this would include studies of air currents . . . ."

3. *Assessment of worldwide plant disease losses through remote sensing and other techniques*—The problem of appraisal of plant disease losses and their effect on agricultural production is of primary importance throughout the world. Under this research proposal, guidelines for the kinds and methods of research necessary to a valid assessment will be established, and locations that will be most desirable and productive will be determined.

These three proposals were reviewed at the Paris meeting of SCIBP in April, 1966, and they have been accepted by the U.S. National Committee for IBP.

The Council of APS has appointed the following committee on IBP: W. D. McClellan, Chairman; E. H. Barnes, H. E. Heggestad, E. P. Imle, R. R. Nelson, R. D. Schein, L. Sequeira, J. R. Shay, W. C. Snyder, and H. R. Thomas. Most of the committee members are chairmen of various subject-matter committees.

This APS Committee will not undertake to organize and manage any one of the three above-mentioned projects nor any other projects that might be proposed. It will serve as a stimulating and coordinating committee for IBP projects of interest to the APS, and will encourage plant pathologists in the United States and elsewhere to cooperate and participate in IBP projects. It will search for and suggest sources of support for the IBP projects. It will encourage and promote cooperation with other world organizations such as the World Meteorological Organization (WMO), and the Food and Agricultural Organization (FAO) in research related to the Society's proposals. For example, the committee is currently active in bringing together a small group of people in the United States interested in atmospheric movement of pathogens (both plant and animals), allergens, arthropods, and chemical air pollutants. These groups will determine how to share their interests, know-how, and research support most effectively.

In March 1967, the APS Committee met and

[1] J. M. Daly, A. E. Dimond, E. P. Imle, R. G. Grogan, G. H. Hepting, Arthur Kelman, G. C. Kent, W. D. McClellan, J. D. Menzies, P. R. Miller, M. N. Schroth, W. C. Snyder, H. R. Thomas, R. A. Young, and G. A. Zentmeyer.

Material in this section was provided through the cooperation of various National Committees and the staff of *Biosphere*, published by the Special Committee for IBP.

formed three subcommittees which were assigned to the three research areas. Currently, suitable research proposals are being solicited. The committee is also planning a work conference to be held in London in 1968, following the general meetings of the Phytopathology Congress.

Productivity of Marine Communities

SECTION committees of both Productivity of Fresh Water Communities and Productivity of Marine Communities have noted the Atlantic salmon as a fish of great economic importance and food value, dependent almost entirely on the productivity of the seas. The total annual catch, and hence presumably the total population in the sea, appears to have been reduced to about one-tenth of its former exuberance since about 1800, through human interference with the freshwater breeding grounds. Now, however, the techniques of artificial rearing of salmon smolts enables the freshwater link to be cut out of the life cycle, so there is an opportunity to recreate the former very large salmon population. The IV Meeting of SCIBP (Steering Committee International Biological Program) passed a resolution on this subject for the attention of the international fishery organizations concerned, and the countries which have, or formerly had, important salmon fisheries.

Activity in Latin America

ALTHOUGH Argentina, Brazil, and Chile have recently established IBP National Committees, Latin America as a whole remains one of the regions in which there has been comparatively little activity in the early months of IBP. Signs of increased activity are becoming evident, however. Section CT (Conservation of Terrestrial Communities) held a meeting in July at Rio de Janeiro to discuss Latin American problems with conservationists from Brazil. This meeting and other factfinding visits were designed to lay the groundwork at the scientific level for a regional conference on conservation in Latin America planned for 1968.

Eutrophication of Waters

EUTROPHICATION is the gradual increase of nutrients and the resulting decrease in the quality of fresh waters. The process is observed all over the world and it stems from industry and agriculture.

The gravity of the situation was expressed internationally by two meetings—one at Lucerne in May 1967, to discuss a report on the state of eutrophication in Europe and North America, and the other at Madison, Wisconsin in June 1967.

U.S. National Committees

EMERGING action programs in both planning and research are beginning to increase within the US–IBP efforts. Recent actions of the committee include (a) establishment of a panel for aerobiology, (b) approval of a program on the ecology of migrant populations, and (c) approval of a program on phenology.

Other programs (still in the planning stage at press time) include: (a) adaptation of peoples at high altitudes, (b) latitudinal and longitudinal variations in marine species, (c) adaptive processes of hybrid and primitive populations, and (d) interactions between plants and insects and between plant species. In connection with the latter, a working conference is being planned for early 1968 at Santa Barbara, Calif., from which one action program may develop because of the widespread interest.

FORUM

Funding Research Effort

I CAN identify two subliminal polar extremes among research administrators as to their outlook on funding research effort. At one extreme are those who regard their task as that of funding researchers. At the other extreme are those who regard the task as that of funding research projects. I believe that these two extremes in subliminal administrative attitudes have important implications to:

1. The role of the research directors.
2. Program and project structure.
3. The flexibility and orientation of the research program.
4. The documentation of research.
5. The coherence of the research system.

I believe that if all research directors would adopt the concept of funding projects rather than researchers, the quality of research administration in our agricultural research system will be greatly improved. Actually, the subliminal attitude that it is researchers who are really being funded may even be incompatible with the extension of modern public administration into research and development.

Experiment station directors who subliminally or explicitly believe they are funding researchers rather than projects are not very concerned with scrutinizing research projects. To them a project is a sort of charter, or at best the articulation of what the scientist is thinking and planning to do. As a result they submit nearly anything a researcher proposes—even believing that the details are none of their concern. This kind of director can be very conscientious because in addition to placing his trust in the researcher he also places his onus for achievement upon the researcher. This relationship of trust and confidence is often idealized by researchers and certainly simplifies research administration.

The attitude that it is researchers, rather than projects, that are being funded is rooted in history. Great patrons of the arts and sciences in centuries past funded individuals and not project proposals. Today, academic freedom concepts, tenure, and the supposedly high social status of professors—all tend to perpetuate and reinforce this attitude.

Those administrators who operate with the attitude that research projects are being funded are inclined to feel that a project is a conceptual entity and that the researcher should put it fully on paper so it can be evaluated. In other words, it is not the act of articulation that creates the project. These administrators are far more inclined to develop research goals and objectives, integrated research programs, and a project evaluation system. I believe this type of administrator is more apt to give strong financial support to researchers who are productive and have many good project ideas. An administrator who thinks in terms of funding research projects also is more inclined to hold budget discussions with department heads and even call in individual researchers. I firmly believe this concept should be promoted, although in special circumstances I would favor explicit funding of some outstanding researchers. Such a procedure could become a status symbol and add to the incentive system. In other words, we should distinguish the trailblazer from the regular scientist.

I believe in this concept—funding projects rather than researchers—for a number of reasons. In the first place, the status of science in society has changed drastically over the years and even within the past few years. Research is now big business. Science has explicitly become a directed servant in the service of man. Science has lost much of its awe—there are too many researchers to be known individually. Also, we are living in a society that is becoming increasingly impersonal and standardized—even in the selection of research methods. What the researcher wants to do may be less relevant than what society wants him to do.

This subliminal difference in viewing the allocation of research funds also has its impact upon the

attitudes of researchers and research administrators toward the documentation of research effort. A researcher who believes a project is supposed to be funding him individually tends to write projects with broad general objectives and procedures. He proposes general methodology rather than specific procedures that have a terminating point.

Research administrators of the same philosophy will accept and support such project statements. They are also more inclined to consider each researcher as being sovereign, unique, and—once established—entitled to continual funding, even when the researcher alone decides what he is to do. To a certain degree, the concept of academic freedom carries the idea that once a professor is hired he has a lifetime social contract directly with society that bypasses administrators.

These subliminal attitudes also have an impact on flexibility in research orientation. The concept of funding the researcher tends not only to foster insulation of the researcher from the concerns of society. It also deliberately short circuits one of the major purposes and functions of research administration—the alignment of research effort with the concerns of society.

There have been quite a few instances where researchers, once they got started in a given line of study, have spent the rest of their lives on the same set of problems despite the fact that the concerns and problems of society and the agricultural situation have greatly changed.

Even in the hiring of new people and the expansion of research into new problem areas—as when additional funds above cost increases are appropriated—some research directors seem to subliminally think in terms of funding researchers instead of projects. In such circumstances they may be more inclined to think in terms of hiring an outstanding individual for the sake of excellence rather than finding the researcher who is best qualified in a highly urgent problem area and possibly one who is more concerned with the problems of society than his own curiosity.

Stating the obverse, the research director who thinks in terms of funding projects will be more concerned with the needs and interests of society and have far more confidence in his ability to build an outstanding research program by careful selection of projects and intellectual leadership. Also, he feels he can elevate research quality through effective project administration.

In my ideal model, a research director would think principally in terms of funding projects, but in a relatively few cases of obvious and undoubted excellence he should explicitly and purposively fund the researcher.

Public administration as a science was slow to get into research administration. Now that science has become big business and an everyday working tool of society, it was inevitable that research projects and programs should receive the same administrative and political scrutiny that action programs have long been given.

It is also true that modern public administration prefers to be impersonal in its dealings—that is, evaluate and depend upon individuals less and to put more confidence in the processes of administration. Because of this, research directors who subliminally or explicitly think in terms of funding researchers rather than projects tend to be at odds with the application of modern public administration to research. They may even be incompatible with the current effort to realign the whole research establishment to be more consonant with the needs and concerns of society.

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